INNOVATIVE METHODS FOR THE ASSESSMENT OF HAZARDOUS WASTE ON REMEDIATION AND CONSTRUCTION PROJECTS

by

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ABSTRACT

The hazardous waste remediation process is completed through multiple phases each served by differing professions. First, geologists, hydrogeologists, the EPA and consultants complete a site assessment and investigation at a potential hazardous waste site. The environmental engineering and consulting professionals are then responsible for providing design services. Finally, construction professionals are acquired to implement the design. This process, although simple on the surface, is extremely time dependent and regulation driven. For some of the large Superfund projects an actual "clean" objective is years and years in the future. The excessive time requirements and cost increases that have been encountered with remediation projects are improving; however, comprehensive efforts are still needed to streamline the entire process.

The work in this thesis is a tool for the remediation manager. The focus is on methods that have been used to improve site investigations on either hazardous waste remediation projects or construction projects with suspected contamination. New methods such as Field Analytical Methods (FAMs), developing a conceptual hydrogeologic model and the Superfund Accelerated Cleanup Model (SACM) will be discussed. In Part I of this thesis, the problems with typical site investigations will be examined. It is emphasized that these problems have not arisen from bad management so much as from inexperience with hazardous waste projects in the past. Only recently has the experience gained in the 1980s been used effectively to change the process. Part II of the discussion outlines the streamlining methods and analyzes their application with case studies.

Therefore, this manual is intended to serve as a manager's guideline for streamlining site investigations. The case studies and discussion help to illuminate management practices and decision making processes which have led to time and cost savings during hazardous waste site assessments and investigations.

Thesis Supervisor: Charles H. Helliwell
Title: Senior Lecturer, Department of Civil and Environmental Engineering

To my Mother

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I would like to thank Charles H. Helliwell, Thesis Advisor, for his help and encouragement. I also thank him for facilitating my switch to the Construction Engineering and Management curriculum at the Massachusetts Institute of Technology. Also, I would like to thank all of the members of the Consortium on the Global Environment and the Construction Industry for their input and guidance.

BIOGRAPHICAL NOTE

The author came directly to the Massachusetts Institute of Technology after four years of study at the University of Notre Dame. He is a 1994 graduate of the University of Notre Dame where he majored in Civil Engineering.

Mr. Caulfield decided to switch from the structural engineering group at MIT into the Construction Engineering and Management program. Searching for research led to his participation with the Consortium on the Global Environment and the Construction Industry. Participation in this group has led to a broad understanding of issues in the hazardous waste remediation market.

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1. INTRODUCTION

The Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), also known as Superfund, has been plagued with problems since its inception in 1980. Typically the remediation projects governed by Superfund are divided into three phases; investigation, design and construction. Efforts in all of these areas are being attempted to improve the efficiency of the entire process. For instance, Field Analytical Methods (FAMs), also known as field screening methods, are being used in the investigation phase to replace time consuming laboratory analysis. Also, presumptive remedies are being used to ease design and investigation issues. Finally, innovative contract strategies such as the Total Environmental Restoration Contract (TERC) are being used to speed the entire process, particularly construction.

One area where these problems are most evident is in the site investigation phase of a remediation project. The site investigation process is typically the most time consuming portion of a site remediation. This process is inefficient for many reasons. First, a thorough site investigation must be completed due to strict regulations. For instance, contract laboratories are still required to be used so that data may not be easily challenged in court by Potentially Responsible Parties (PRPs). Also, site investigations have been inefficient due to the youth of the profession in the 1980s. Many Superfund projects are finally nearing completion allowing for a look back into past problems. Site investigation problems may also be analogously applied to typical construction projects.

As redevelopment of industrial and inner-city properties becomes more prevalent, hazardous waste assessments will be needed. It is evident from site assessments and investigations that have slowed Superfund efforts and delayed construction projects that the process of collecting samples, testing, waiting for results and re-testing needs to be streamlined. Improvements to the investigation phase of a project will result in cost and time benefits on remediation projects and reduce unexpected delays on construction projects.

In the future there will be a constant demand for new technologies and management practices to improve all facets of the hazardous waste remediation process. With the Republican dominated Congress elected in 1994, there will be a push towards more cost efficient completion of remediation projects. This is evident at sites such as the Norwood PCB Superfund Site in Norwood, Massachusetts where treatment options are being reevaluated after initially deciding on Solvent Extraction in 1989 and later deeming the technology too expensive. The funding for the project has not been guaranteed due to the failure of Congress to reauthorize Superfund and due to anticipated federal budget cuts. Thus, cost efficiency will have to be achieved at the lower priority Superfund sites or funding may eventually diminish. This cost cutting trend will also permeate the site investigation phase of remediation projects. Hundreds of sites have yet to be identified in the United States and many others are currently under investigation. Streamlining at these sites is evident, some of which will be illustrated with case studies in this thesis.

Consulting and engineering firms are typically the parties responsible for assessments and conducting the more detailed Remedial Investigation/Feasibility Study (RI/FS) at Superfund sites. Experts in the fields of geology, hydrogeology, chemistry and hazardous waste all attempt to understand the contamination at a site. These firms will have sustained business in the site investigation phase of a remediation project despite the growing business of remediation/construction. This growth of remediation/construction can be attributed to the progression of many Superfund sites into the treatment phase. Finally, Superfund is starting to achieve its goal of site treatments that were promised in the 1980s. However, this is only after years and years of investigation at some sites. Despite the trend towards remediation instead of investigation, RI/FS revenues still comprised 24% of the hazardous waste remediation market in 1993. The hazardous waste market has been in a slowdown; however, recent trends in the real-estate market have provided some light at the end of the tunnel. The increasing strength of the real-estate market has resulted in investor-driven demands for site assessment and remediation services[1]. With a continuation of this trend, investigation and remediation firms geared to this market should see needed growth. Figure 1[2] illustrates the breakdown of revenues in

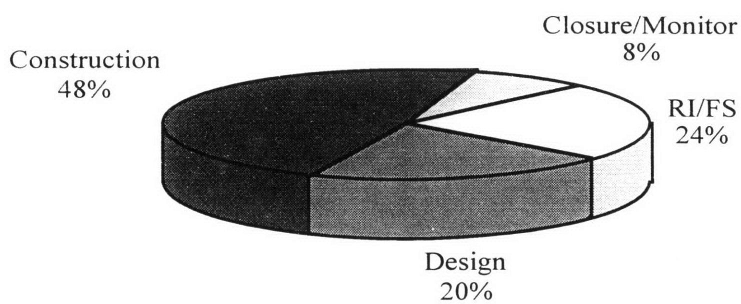

Figure 1: Breakdown of Revenue in the U.S. Remediation Market

the hazardous waste market.

The trend in the environmental market has been a consolidation of services since large turnkey contracts are being awarded more and more frequently. Thus, consulting and engineering firms have been acquiring in-house construction services. Also, construction firms have begun increasing in-house investigation expertise. This trend will be examined further in this thesis illustrating the rapid changes in the remediation market. This is combined with an overview of regulations governing site investigations, and an

[1] Barber, Walter C. *Diversification and Cost Reduction when the Going Gets Tough.* Environmental Business Journal. Vol. VIII, No. 1. January, 1995.

[2] *EBJ Executive Summary.* Environmental Business Journal. Vol. VII, No. 8, August 1994.

outline of the Superfund process. Through this, procedures for site investigations as conducted in the 1980s are outlined.

The second part of this thesis presents in detail the decision making process behind methods to improve site investigation services. The first and most influential method discussed is the use of Field Analytical Methods (FAMs) also known as field screening methods. Two case studies are examined in this area. The use of immunoassay technology at the Norwood PCB Superfund site is discussed along with specific sampling needs that were used to implement this new technology effectively. Second, the use of field screening on the Central Artery/Tunnel Project in Boston, Massachusetts is outlined in detail. Special guidelines have been used to effectively delineate contaminated soils with subsequent disposal. This case study is especially interesting since it is not a Superfund project and is typical of potential contamination findings on construction projects. This type of field screening will become particularly useful as city redevelopment projects and land reuse programs become more prevalent in the United States. Contractors will more frequently encounter the wastes of past property owners and will need to understand the regulations and methods to assess the magnitude of contamination. This will aid in avoiding the potential delays and changes associated with differing site conditions. Both case studies delineate the cost and time benefits of using FAMs in addition to addressing the determining factors for the use of these innovative methods. The two case studies also provide interesting insight into the cooperation of regulators for the use of field analytical methods. At Norwood the immunoassay technology was used without inhibition while on the Central Artery project the use of these techniques has been extremely limited due to the risk averse atmosphere on the project.

The second area that is examined for improving site investigations is the development of a conceptual subsurface hydrogeologic model for groundwater investigations and remedial designs. Typically, Superfund professionals have not expended the potential for understanding groundwater flow previous to subsurface monitoring with wells. This has led to increased costs by constructing and sampling wells with no contamination. The hydrogeologic modeling process at the Massachusetts Military Reservation is discussed along with its application to several groundwater contaminant plumes. Also, the power of computer modeling becomes evident as it is applied to plumes to allow for better understanding of contaminant flow in the subsurface. The conceptual model along with computer modeling will aid in the placement of expensive groundwater monitoring wells saving both time and money in the site investigation phase. The downstream advantages of this conceptual model will also be covered.

In order to clearly understand the following material, the distinction between assessments and investigations is outlined. Typically, a site is identified as a potential hazardous waste site by an agency such as the EPA. The site then undergoes an initial review which is referred to as an assessment. Several parties such as the removal (emergency) arm of the EPA as well as the remedial (long-term treatment) arm will conduct assessments. Usually, soil and groundwater test samples are not taken during assessments. Investigations, on the other hand, require comprehensive sampling of soil and groundwater and analytical testing for contaminants. These investigations are usually conducted over a long period of time and large quantities of data are generated.

The preceding innovative methods will provide benefits primarily in the investigation phase of a remediation project. The Superfund Accelerated Cleanup Model (SACM) provides benefits in both the preliminary assessment stages as well as in the remedial investigation phase. SACM is an effort to integrate all Superfund activities toward the front end of the process. For instance, one effort is to integrate removal and remedial assessments that were formerly separate activities. This integrated assessment focuses on data collection that will aid the remedial investigation phase. The efforts of SACM that influence assessments and investigations are covered thoroughly. Also, a case study of a farm site in Missouri with dioxin contaminated soils shows how SACM's flexibility changes a site investigation methodology.

Finally, recommendations are made regarding a general approach for site assessments and investigations. Through the case studies that are illustrated, methods to streamline investigations are discussed and advantages and disadvantages of the methods are outlined. These methods serve as guidelines for the remediation or construction manager when attempting to conduct cost and time efficient site investigations.

PART 1: OVERVIEW OF REGULATIONS AND SUPERFUND SITE INVESTIGATION PROCEDURES IN THE PAST

2. *OVERVIEW AND BACKGROUND*

2.1.Environmental Legislation

In 1976, the push towards a more sustainable society was initiated. This was the beginning of the movement to control hazardous and solid waste at point sources and strictly regulate disposal. Eventually, regulations were written to address the cleanup of the hazardous waste problems created by many years of unregulated industry dumping. These regulations are broad sweeping and give the EPA and the government extensive powers to hold industries accountable for their current and past dumping practices. Overall, these regulations have helped to address the dumping and treatment of hazardous and solid waste. Although they have been inefficient in many ways requiring amendments, the message has been delivered to industries in the United States. Not only will unlawful dumping not be tolerated, the EPA has also shown their intention to hold all parties responsible for past dumping. Thus, the regulations discussed below have been inefficient in many ways but still effective in pushing industries towards thinking environmentally and addressing their waste production problems.

2.1.1. The Resource Conservation and Recovery Act (RCRA)

This act was first enacted in 1976 as a culmination of several years of sparse environmental law-making. Basically many pieces of legislation were enacted and RCRA served to unite many of the concepts demonstrated in each. RCRA governs the process by which hazardous and solid waste is disposed. This was one of the first regulatory acts that gave the EPA sweeping authority. The EPA was empowered to regulate all aspects of the disposal of hazardous waste. In summary this document has several key provisions outlined below[3].

- Requires identification and tracking of hazardous wastes as they are generated.
- Establishes the materials that are regulated and deemed hazardous.
- Requires permitting of hazardous waste disposal facilities that must comply with EPA standards.
- Requires states to develop hazardous waste management plans.

In 1984, RCRA was amended to account for some of the shortcomings in the original regulations. Mainly, this involved the addition of underground tank regulations and also added smaller hazardous waste generators to the requirements listed above.

2.1.1.1. Implications for Site Investigations

RCRA governs the care of hazardous wastes as they are generated from active sources of waste generation. This regulation does not have a direct affect on site investigations; however, it may have some implications on two levels. First, underground tanks are governed by the RCRA regulations. Leaky tanks have been a major source of contamination and, in most cases, investigation services have been needed to identify whether a tank has leaked and to what extent. Also, RCRA governs the assessment monitoring programs at hazardous and solid waste disposal sites. Investigation services are used at these sites to monitor potential groundwater contamination from leachates and to treat them if the need arises. Thus, the remedial manager must be aware of RCRA regulations when dealing with leaky tanks and the disposal of wastes.

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[3] Jain, Ravinder K. Ph.D., P.E. *Environmental Legislation and Regulations.* Handbook of Environmental Engineering. Chapter 2.

2.1.2. Superfund

The Superfund legislation passed in 1980, officially the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), has received by far the most press and public attention in the United States due to the highly publicized contamination problems such as New York's Love Canal. Hazardous waste at this site dumped over a period of 25 years had contaminated soils, streams and groundwater. The hazards were so serious in fact that several hundred people had to be evacuated. After this, "The Valley of the Drums" in Kentucky also gained front page headlines. This sight was an obvious hazard with leaking barrels of hazardous waste. Also, the Times Beach site in Missouri made news due to contaminated oil that had polluted the community's soil and water with dioxin[4]. Nearly 2200 people had to be relocated at a cost of $33 million[5]. These extreme contamination problems haunted the communities that had to endure them. It also sent a message to Congress to implement tougher hazardous waste legislation. Thus, from the momentum gained due to these high profile hazardous waste sites, Congress developed the Superfund in 1980 with funding of $1.6 billion.

The Superfund legislation gives the EPA substantial power to hold past polluters responsible for their actions. A database, called CERCLIS, has been gathered as part of Superfund listing potential hazardous waste sites. This database has in it more than 35,000 potential Superfund sites. The EPA uses the procedures set up in Superfund to address the hazards at these sites and to identify the parties responsible. If needed, the EPA has the power to conduct removal (emergency) actions to reduce immediate risks to communities. This power was increased with the passage of the Superfund Amendments and Reauthorization Act (SARA) in 1986. SARA addressed right to know laws for the public and also addressed further measures to handle emergency situations on the state and local levels. Also, SARA reauthorized Superfund for another five years with funding

[4] United States Environmental Protection Agency. Superfund: Focusing on the Nation at Large. Office of Solid Waste and Emergency Response. Pb92-963252. September 1991. Page 1.

[5] Boraiko, Allen A. *Storing Up Trouble...Hazardous Waste.* National Geographic. March, 1985. Page 341.

of $8.5 billion. Currently, the Superfund is diminishing with potential reauthorization pending in 1996.

2.1.2.1.Joint, Strict and Several Liability

Superfund gives the EPA the power to hold parties responsible for past dumping of hazardous wastes. However, it is interesting since the EPA can force a responsible party to pay for cleanup even if the dumping practices were legal at the time the contaminant was released. Thus, some firms have been held responsible for contaminants dumped years ago in a perfectly legal manner. This is referred to as strict liability, an indication of absolute liability. Since the party dumped the waste there in the past they are considered absolutely responsible. Also, the EPA has the power to hold one party responsible for cleanup at a site even though many parties were responsible for the dumping. It is the responsibility of the liable party then to seek retribution from the other past contributors to contamination. This is also significant since a party can be held responsible for a disproportionate percentage of contamination at a site. This form of legal enforcement is called joint and several liability.

These legal factors have led the EPA to challenge parties for compensation in court. If the EPA does not recover moneys, the Superfund will cover the cost of cleanup. Thus, Superfund technically should pay for itself; but, the lengthy court battles with PRPs have been expensive and time consuming, draining the Superfund. The EPA has such sweeping authority in fact that if a responsible party refuses to comply with an EPA order and the site is cleaned up under Superfund authority, EPA may seek "treble damages"[6]. With this, the uncooperative responsible party may pay up to three times as much as the actual cleanup cost under Superfund. Thus, in many cases it is in the company's best interest to cooperate and fund the cleanup of the site. Not only will initial litigation costs be reduced, but a potential requirement to pay up to three times the

[6] United States Environmental Protection Agency. Superfund: Focusing on the Nation at Large. Office of Solid Waste and Emergency Response. Pb92-963252. September 1991. Page 1.

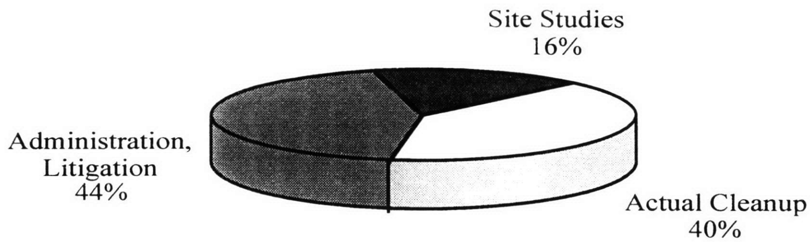

Figure 2: Breakdown of Superfund Expenditures as of 1989

cleanup cost will also be avoided. Despite this, many companies choose to fight the allegations and the costs of EPA cleanups. This litigious atmosphere is so bad in fact that the Office of Technology Assessment has determined that 44% of Superfund dollars have gone towards administration, litigation and related activities[7]. A further breakdown of costs is seen in Figure 2.

2.1.2.2. Contract Laboratory Program

The litigious environment created by the Superfund legislation has had significant effects on the site investigation phase of a remediation project. As discussed previously, the assessment and investigation phase can last for as long as ten years on a Superfund site. This is mainly due to the strict guidelines that must be followed to obtain data that will hold PRPs responsible in court. Thus, site investigations have focused more on obtaining data to hold PRPs responsible than actually delineating contaminant areas and plume movement. The EPA requires the use of the Contract Laboratory Program (CLP) since data must be of laboratory quality to hold up in court. In fact, the laboratory business has grown substantially due to the need for strict quality control enforcing Superfund litigations. The problems with laboratory analysis are high costs and long turnaround times for testing. Typically, 3-4 weeks are needed to obtain results and each sample costs around $300. With hundreds of samples and several investigation efforts being completed in the life of a project, it is easy to see why the site assessment and investigation phase can last up to ten years. Thus, the litigious nature has required the

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[7] *Coming Clean - Superfund Problems Can Be Solved*, Office of Technology Assessment, OTA-ITE-433 (Washington, D.C.: U.S. Government Printing Office, October, 1989).

EPA to use laboratories and obtain data of high quality. However, this is one of the main reasons for excessive time and money expenditures in the investigation phase.

2.1.3. State and Local Legislation

Several states have taken strong initiatives to develop their own solid and hazardous waste legislation. Massachusetts, New Jersey and California are on the forefront of state legislation. Massachusetts has developed its own legislation similar to Superfund and RCRA regulations. The Massachusetts Contingency Plan (MCP) is a set of regulations that are derived from the Massachusetts General Law which is essentially the state Superfund law[8]. This law is unique since it is attempting to change the slow moving, expensive cleanup process found in Massachusetts. The MCP will achieve this by allowing Licensed Site Professionals (LSPs) to govern the cleanup of hazardous waste sites and emergency spills. The use of LSPs changes the common practice in hazardous waste legislation by not requiring approval of all decisions by a regulatory group[9]. The LSPs will be responsible for all phases of remediation from governing site assessments and investigations all the way through site closure. Thus, finally some attempts will be made to enhance the speed and efficiency of site cleanups in Massachusetts. 5800 property holders in the state are hoping that this will aid in ridding themselves of the liability they hold with contaminated sites. Therefore, private professionals in Massachusetts will now be responsible for understanding and managing the entire remediation process. The streamlining methods outlined in this thesis will prove useful to these state sponsored cleanups managed by LSPs.

2.2. Methods to Obtain Site Investigation Services

This section focuses on the several methods that have been used to obtain services for the hazardous waste cleanup market. The following discussion of the traditional

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[8] Campion, Jack, P.E. and Walsh, Catherine. *The New Massachusetts Contingency Plan: The Promise of Privatization of Hazardous Waste Site Management.* Camp Dresser & McKee Inc. Cambridge, Massachusetts.

[9] Ibid.

method used in the 1980s outlines advantages and disadvantages. Unfortunately, changes involving innovative contracting methods have been slow in coming. Initiatives by such organizations as the Department of Defense (DOD), the Department of Energy (DOE), and the United States Army Corps of Engineers (USACE) have started the change towards more environmental restoration contracts. These contracts are broad in nature and are tailored to those cleanup firms offering cradle-to-grave services. Thus, firms such as OHM Corporation and Foster Wheeler Environmental Corporation are well positioned to win these large contracts. This confirms the trend in the hazardous waste industry as the spectrum of U.S. providers will be made up of larger, full service firms and small, niche players[10]. There will be few firms that occupy the middle of the spectrum.

2.2.1. Traditional Method

The EPA has typically acted as the owner especially at the outset of remediation projects since responsible parties have been reluctant to take the lead with cleanups. Typically, the EPA subcontracts for all services leading to a remediation. This type of structure for completing hazardous waste projects has proven very inefficient. The same inefficiencies are evident on typical construction projects where design and build functions are separated. Enormous amounts of data have been generated in the

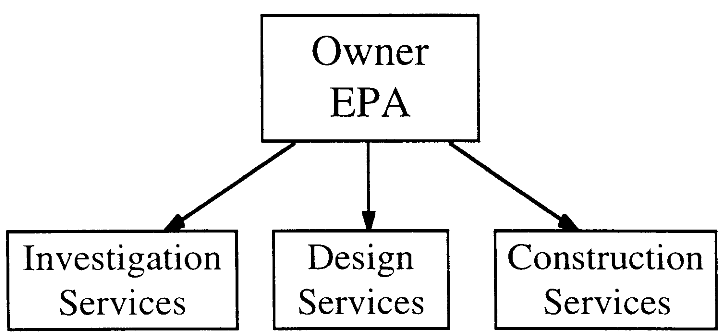

Figure 3: Traditional Remediation Method

investigation phase of typical Superfund projects. The results are then transferred to the designers. However, in most cases, the investigation parties do not obtain the

[10] Rocca, Vincent A. Dr. *The Globalization of Environmental Markets*. Environmental Business Journal. Vol. VIII, No. 1. January, 1995.

appropriate data needed by the designers. Coupled with this there is a lack of trust between the parties due to the liability potential in any hazardous waste work. Thus, in many cases, the designers on Superfund projects must complete investigations of their own. Finally, obtaining construction services separately of design also causes more headaches and delays. The end result with the traditional method displayed in Figure 3 is a slow and inefficient process with needless repeated work. As is seen in the following sections, efforts are underway to mitigate these problems.

2.2.2. Current Trends

The hazardous waste market has been changing due to the different contracting methods that were mentioned previously. The EPA is finally using the experience gained in the 1980s and encouraging innovative contracting methods. The setup shown in Figure 4 illustrates the transition to a turnkey approach that is occurring in the remediation market. This stems from the consolidation of the industry. The large consulting and engineering firms have been acquiring in-house construction services. Also, construction

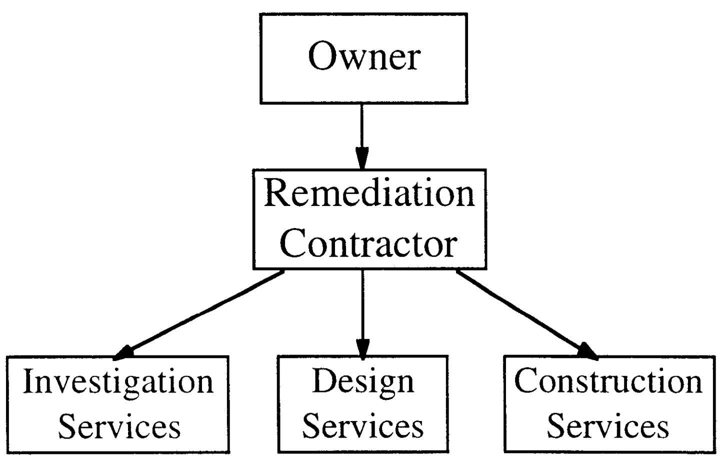

Figure 4: Current Trends in Remediation Project Procurement

firms have been acquiring their own design and investigation services. Although this transformation is only beginning, firms have begun to sell themselves as having multiple services and one-stop shopping. Typically, these firms have their core competency in investigation and design or construction and will subcontract to cover their lack of inexperience in other areas. This consolidation signals a transition to the future expected state of the remediation industry with one-stop remediation shopping.

2.2.3. The Future of Remediation Project Procurement

Currently there are many projects underway that are using a version of the future model illustrated in Figure 5. For instance, the United States Army Corps of Engineers is using a new innovative contract strategy called the Total Environmental Restoration Contract (TERC). This contract is awarded to a remediation contractor for a ceiling dollar amount for the remediation of several sites in a region of the country. For instance, Foster Wheeler Environmental Corporation has been awarded a TERC in the amount of

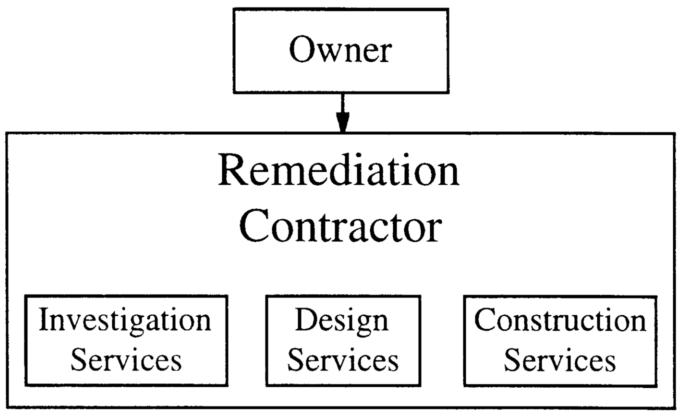

Figure 5: The Future of Remediation Project Procurement

$260 million to clean sites in New England. Foster Wheeler is guaranteed a certain amount of work in that contract to the ceiling amount of $260 million. This contract calls for cradle-to-grave treatment of several Superfund sites. Thus, Foster Wheeler is responsible for all services including investigation, design and construction.

The procedure for awarding work under this New England TERC contract is to designate a delivery order for a particular portion of a project. Foster Wheeler is then awarded a pre-delivery order amount in some cases to prepare a proposal for the work. Finally, the USACE and Foster Wheeler sit down and negotiate the proposal to be awarded with a fixed percentage of the cost of work as profit. One case where the TERC has been extremely useful is illustrated in the Norwood case study developed for this thesis. The EPA declared in the ROD that the equipment in one of the buildings on the site would be cleaned. When the owners of the building decided they wanted to sell the equipment the EPA and the USACE had to move into action quickly. The TERC allowed a perfect contract mechanism for this delivery order. The USACE immediately notified Foster Wheeler of the proposal and they went to work on the equipment decontamination project. Since Foster Wheeler was already aboard with the TERC, the response was instant. Also, Foster Wheeler is one of the firms that has consolidated and maintains in-house expertise in all phases of a remediation project. Thus, Foster Wheeler instantly put there investigation expertise to use and designed the sampling plan for the equipment. Also, the remediation method to wipe the equipment with a solvent was proposed. Thus, Foster Wheeler was able to use all of their forces to design a remediation method for the equipment. The project was successfully completed by Foster Wheeler in approximately 10 months cleaning 56 pieces of machinery with accessories for release and sale. The delivery order was definitely a success for the TERC and a demonstration of innovative, efficient contracting.

3. THE SUPERFUND PROCESS (OVERVIEW)

The EPA, at the advent of CERCLA in 1980, started to outline a methodology for Superfund that would prove somewhat uniform and cost effective. This is a difficult task due to the site specific considerations on each remediation project. Hazardous waste sites run the spectrum from small, emergency action cleanups to huge, long term groundwater and soil remediations. Sites range dramatically in size from 1/4-acre metal shops to huge 250 acre mining areas. Also, the types of contaminants that Superfund addresses are extremely diverse. Thus, it is difficult to describe the typical hazardous waste site in the United States. This has only added to the difficulty of writing effective and efficient legislation to correct the nation's hazardous waste problems.

The first step in the Superfund process is the Preliminary Assessment (PA) which involves a literature review and a review of past businesses functioning on the site. Preliminary assessments are conducted for all sites on the CERCLIS database. This initial review of records and site visit identifies the threat that is posed by the site. At this point in the process, three possibilities exist. First, if the site is deemed to pose no threat, it is usually referred to the state treatment level. Second, if the site poses an emergency situation, a removal investigation will be conducted delineating the immediate risks to the community. The threat is then addressed under guidelines in the National Contingency Plan (NCP). If the site qualifies, an emergency action will be conducted. In the event the site does not qualify for an emergency action on the federal level, it will again be referred to the state. Third, if the site poses a long term threat it will enter the remedial branch of the federal remediation process. The site will then undergo an expanded preliminary assessment also referred to as an Expanded Site Investigation (ESI), the purpose of which is to gather data to score the site on the Hazard Ranking System (HRS). If the site scores above 28.5 on the HRS taking into account such factors as exposure pathways and likely contaminants, it is added to the National Priorities List (NPL) and becomes eligible for Superfund moneys. If the site does not score above 28.5, it is transferred to state authorities.

After a site is added to the NPL, the site is officially known as a Superfund site. At this point the project may have been in the federal process for as long as five years. The Remedial Investigation/Feasibility Study (RI/FS) is then conducted which is a comprehensive study of all media contaminated at the site. An illustration of the Superfund process is shown in Figure 6.

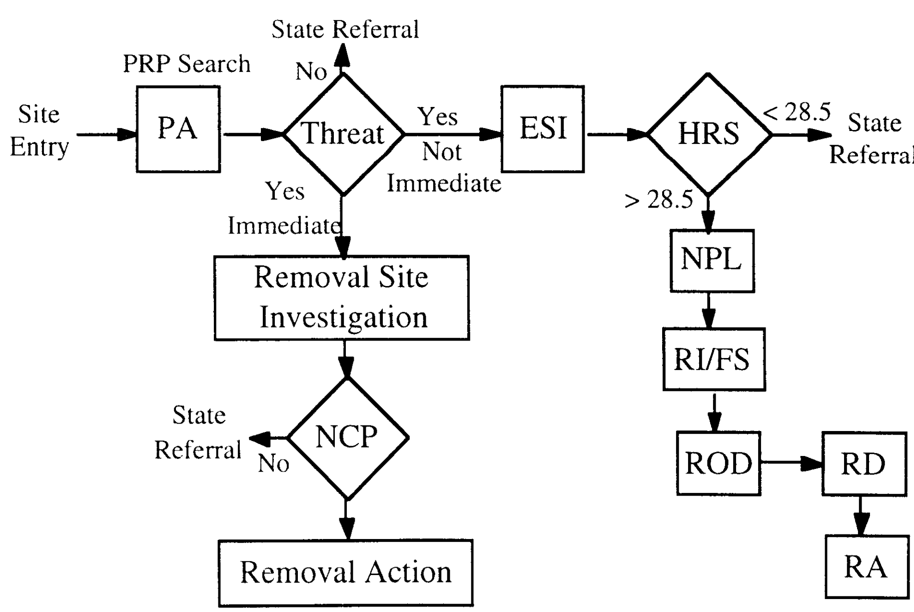

Figure 6: Diagram of the Superfund Process

The RI/FS may be completed by Superfund contractors or by a contract with the PRPs. The RI focuses strictly on determining the area, extent and magnitude of contamination at a site. This process has become known as "plume delineation". The usual method for implementing this process is to complete a drilling, sampling and analysis scheme. The data is then incorporated into the RI report which outlines the extent of contamination at the site. Concurrent with this process is the Feasibility Study (FS) which determines the applicability of treatment technologies. After completion of the RI/FS a Record of Decision (ROD) is issued which states the appropriate remedy. Finally, the Remedial Design (RD) is completed by an engineering firm and the Remedial Action (RA) is implemented with a construction contractor. After this fragmented process is completed, site closure and restoration is achieved.

3.1.Problems with Superfund

Superfund has had a turbulent start especially in the view of the public and members of Congress. Everyone agrees that Superfund needs amending; however, compromise between industry, the government and EPA has made matters difficult. The preoccupation with more pressing issues has caused Congress to put off Superfund reauthorization in 1994. Thus, the funding for site cleanups will soon run out. Many of the problems with Superfund lie in the fragmentation of the entire process. Just looking at all of the independent assessments and investigations that may occur, it is obvious why few sites have actually been cleaned.

3.2. The Superfund Site Investigation Process and its Problems

This section focuses directly on the Superfund site investigation process and all of the parties that are involved and their functions. First, the entire Superfund site investigation process must be isolated and each stage explained carefully. With this, the difference between assessments and investigations are outlined more thoroughly. In the review of the overall Superfund process (Figure 6) the removal and remedial activities were displayed as one activity for simplicity. However, these two treatment branches have handled assessments and further investigations separately. An illustration of the two approaches is given in Figure 7.

The first stage of the entire investigation process is the preliminary assessment (PA). This is a preliminary function for both the removal and the remedial branches of the EPA regulatory process. This portion of the process is conducted separately by both removal and remedial investigators. Typically, the EPA is notified of a potential release at a site and the site is visited by an On Scene Coordinator (OSC). If the site warrants an emergency action then the site may be sampled for the preliminary assessment. Concurrent with this the PA is completed by the remedial branch of the treatment process. The focus of this separate PA is to gather information from the site that will allow it to be scored on the HRS. This data is usually obtained without sampling. An example of this is determining: the population within a quarter mile of the site; exposure

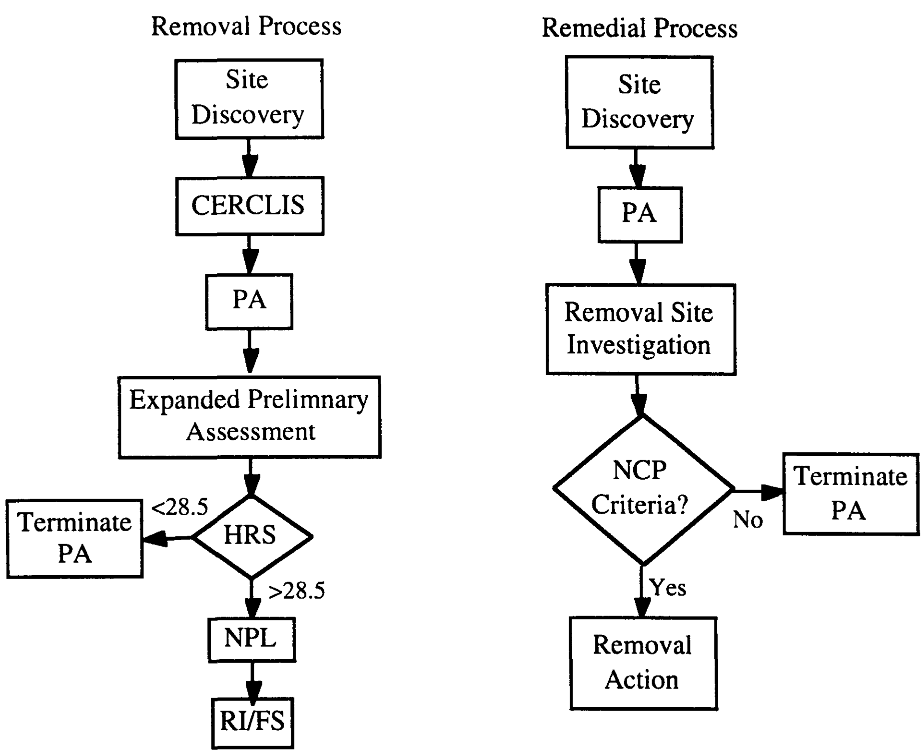

Figure 7: Superfund Removal and Remedial Site Investigations

pathways; and likely contaminants. In general, the remedial site assessment process is more structured than the removal assessment. The removal assessment operates on a more intense schedule and data is gathered in order to confirm whether the site meets qualifications for a removal action as designated in the National Contingency Plan (NCP).

The threat at the site is evaluated by each of the parties. If the site poses an immediate threat, a removal investigation is completed. The purpose of this investigation is to identify hot spots for removal that were not identified in the preliminary assessment. In general, these investigations are conducted rapidly in order to reduce immediate risks to the public. If the site poses no threat it may be referred to state treatment. The last option is to consider the risks posed by the site for the long term. If the site poses a long term threat then the remedial branch will proceed with the expanded preliminary assessment. Finally, it is important to note that most Superfund sites have many different types of contaminants and many different types of affected media. Thus, most sites require both removal and remedial correction. In many cases assessments are conducted separately and work is needlessly repeated. Efforts have been underway with the Superfund Accelerated Cleanup Model (SACM) to integrate these assessments and avoid repeated work.

The final stage in the investigation process that occurs concurrently with the Feasibility Study is the Remedial Investigation (RI). This is a comprehensive soil and groundwater sampling phase that can take as long as five years. There is a substantial amount of effort put into the RI/FS with a complete work plan developed prior to the commencement of work. The preparations include:

- Development of QA/QC, sampling and work plans
- Cost and time proposal
- Preliminary Risk Assessment
- Identification of Applicable or Relevant and Appropriate Requirements
- Boring and sampling plans
- Data Quality Objectives (DQOs)

Once these plans are complete the remedial investigation begins at the site. This process is tailored well to obtaining data that will prove PRP responsibility in court. The emphasis is on determining the concentrations and area covered by contamination. However, this process is inefficient in many ways contributing to the RI's lack of design compatibility. Much of the data that is collected in the RI is not appropriate or sufficient for the design stage. Thus, more sampling is needed long after the RI has been completed.

3.2.1. "Plume Delineation Method"

The predominant practice for conducting the RI/FS stage of the remediation process has become known as the "plume delineation method"[11]. The purpose of this approach is to gain a comprehensive understanding of the contamination at a site and to determine the appropriate treatment method with the feasibility study. The focus of the RI is to determine the type, magnitude and spatial distribution of the contamination. This phased approach has served its purpose for identifying the rate and extent of contamination; however, it has been an inefficient process[12]. Several improvements may be made to the process as discussed in the second portion of this thesis. This inefficient approach to site investigations has also been called the "shotgun approach" or the "poke and hope" method as illustrated in Figure 8.

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[11] Sara, Martin N. Standard Handbook for Solid and Hazardous Waste Facility Assessments. Lewis Publishers. 1994. Page 10-19.

[12] Ibid.

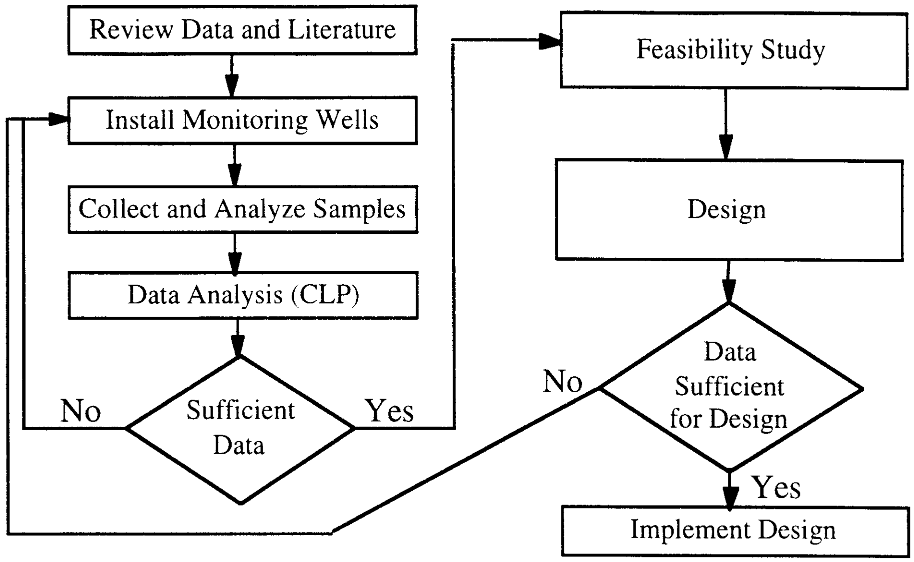

Figure 8: Plume Delineation Method

Initially, a review of background information is completed for each site before the RI begins. After the sampling plan is devised an initial phase of installing monitoring wells and taking soil borings is completed. The resulting samples are then sent to the analytical laboratories licensed by the EPA in the Contract Laboratory Program (CLP). Finally, when sufficient data is obtained from several stages of sampling, the feasibility study may be completed and the ROD is issued. At this point, the data collected from the RI is transferred to the remedial designers along with the selected remedy. In the following section, details about "the shotgun approach" are covered illustrating why it has been an inefficient method.

3.2.1.1.Problems with "the Shotgun Approach"

In all cases an insufficient amount of data is collected in the first phase of the sampling process to properly delineate the rate and extent of contamination. Therefore, additional sampling is needed. In many cases after this initial phase it is discovered that the contamination has spread further than initially expected. Also, sufficient data is usually not available to define the concentration gradients accurately. Thus, typically, many stages of sampling and analysis are required for the RI and laboratory results are needed for each set of samples. This is a distinct problem since analytical results have a 3-4 week turnaround time which adds to the time spent through this process. Thus, site investigation forces must be mobilized and remobilized for each sampling session. This method typically becomes a "plume chase" with sampling teams trying to find the limits of the spread of contamination. Finally, after the remedy is selected in the FS, the design may begin. In many cases, the data obtained in the RI is not sufficient for design and more sampling is needed. The repetitive loops in this process need to be avoided. Obtaining a better understanding of subsurface behavior is a method that should encourage "smart sampling" as opposed to the practice of "saturation sampling" used at many Superfund sites[13].

3.2.2. Site Investigation Repetition

As discussed previously, both removal and remedial investigations are needed at many sites. Unfortunately, these activities are conducted separately and much work is repeated. Also, many other participants in the remediation process will investigate the site including members of the following parties:

- Preliminary Assessment
- Removal Branch
- Remedial Branch
- PRPs
- State Authorities
- Local Authorities

Due to distrust and lack of cooperation there is very little exchange of information between the groups listed above. For instance, the PRPs will collect samples to refute samples collected by the EPA's investigation forces. Obviously, little interaction will take place between them. Although some parties need specific data from the investigation process, many of these efforts may be combined. Thus, it is easy to see why sites have

[13] Ibid.

been assessed and investigated for over ten years. Couple this with the legal battles involved, and the result is very few clean sites even after 15 years of Superfund.

3.2.3. Case Study - The Norwood PCB Superfund Site

Many of the inefficiencies discussed above in the overall Superfund process are seen at the Norwood PCB Superfund Site. Many of the problems are a result of this site being addressed early in the Superfund process. If this site had entered the remediation process today, much of the experience gained in the 1980s would have been used to quell the problems. However, the Norwood site is typical of Superfund sites. Treatments are just starting to be implemented even after 10 years of emergency removals, assessments and investigations by many parties.

3.2.3.1. Discussion of Inefficiencies[14]

As was discussed previously, site investigations have been very inefficient throughout Superfund history. The preliminary investigations conducted at the Norwood site along with the attempt to use these results for the RI illustrate many of the problems with investigations conducted in the 1980's. The review of inefficiencies at the Norwood site serves as a valuable tool for the remediation manager. By assuring that the data collected for any site investigation is of the proper quality, repeat work may be avoided. It is stressed again that these inefficiencies have not resulted from mismanagement, but rather from the general inexperience in dealing with hazardous waste site investigations in the 1980's.

These problems stem from the structure and methods that the EPA requires for the Remedial Investigation/Feasibility Study (RI/FS) process. As discussed previously, the data that is collected through EPA efforts must be of the quality required to be defensible in party litigations. Thus, the EPA establishes strict guidelines for sample quality control. Prior to the RI/FS, Data Quality Objectives (DQOs) are set. These

[14] Information obtained from the Remedial Investigation Report for the Norwood PCB Superfund Site prepared by EBASCO Services Incorporated. June, 1989.

objectives are derived from Applicable or Relevant and Appropriate Requirements (ARARs) which are the federal, state and local regulations and requirements that govern the particular site cleanup. These requirements are then used as guidelines to outline the level of quality that the collected data must meet. For the Norwood RI, DQOs were outlined on a four level scale. These four levels are outlined as follows:

- DQO Level I: Field screening or analysis using portable instruments.
- DQO Level II: Field analysis using more sophisticated portable analytical instruments, mobile screening without standard laboratory analysis of duplicates, or samples taken from previous investigations without exact knowledge of sampling location. There is a particularly wide range of data quality in this level.
- DQO Level III: Analysis using the CLP but with a lower level of validation and documentation than required for level IV. Also, mobile laboratory screening analysis with field QA and backed up with off-site CLP analysis of duplicates to confirm data.
- DQO Level IV: CLP or equivalent analysis. Level IV is characterized by rigorous QA/QC protocols and documentation.

The data that is to be used for legal enforcement or the Endangerment Assessment (EA) must be DQO Level III or IV. Data that is to be used for the Feasibility Study or engineering design must be at least DQO Level II. DQO Level II data may also be used for general site characterization, evaluation of alternatives and monitoring during remediation implementation. DQO Level I may only be used for site safety and health purposes. These guidelines pose a problem that is found at all Superfund sites. At Norwood, there were countless investigations conducted before the RI. This data may have been useful; however, much of it does not fall into DQO Levels III or IV. Thus, the data is relatively useless and can only be used as guidance for the RI. Samples of this insufficient data quality are given below for both surficial soils and groundwater.

A total of six companies and agencies investigated the surficial soils at Norwood prior to the RI. In 1983, prior to the removal action, the DEQE took one soil sample and E.C. Jordan Company took 10 samples. Inaccuracies in the sample location rendered these results invalid for legal enforcement or for use in the design and feasibility studies. Thus, this data was only used for a qualitative assessment of the contamination in the RI. In 1983 during the removal action, Roy F. Weston sampled and analyzed 78 surficial soil samples. Most of the samples were taken from areas where soils were removed. Also, some samples were taken on the Grant Gear property. However, the data collected in these 78 samples was not useful for the FS or the EA since the analytical procedures were not clearly outlined and again sample locations were not exact. Also, there was some confusion as to which samples were removed during the excavation. Again in 1983, after the removal action, samples were taken to verify the effectiveness of the removal. 145 soil samples were taken and were screened on-site with some quality assurance procedures used. However, the CLP was not used to confirm results placing this data in DQO Level II allowing it only to be used to scope the RI. Not until 1986 were better quality results obtained. GZA and Wehran Engineering obtained 127 and 38 soil samples respectively all with the proper laboratory use and quality assurance procedures. This data was used specifically for the EA, FS and engineering design.

Another example of poor quality assurance is seen with the testing that was completed in order to properly characterize the groundwater at the site. In December 1983, WEB Engineering measured the water levels in six wells to determine the groundwater flow directions. It was not clear exactly how the wells were installed. Three of the 5 wells were tested for PCBs with only one revealing any contamination. This data was not used in the RI since more accurate groundwater tests could be completed in 1987. The data collected in these six wells was only used to scope the RI. Also, in 1987, Camp, Dresser and McKee (CDM) sampled seven of eight monitoring wells which had been installed in 1985 by Wehran Engineering. The results were again only used to scope the RI since the wells had not been purged properly before sample collection.

This same pattern of collected data which turns out to be relatively useless when conducting the remedial investigation is a common pattern at Norwood and at most if not all Superfund sites. Further review of the other media sampled at Norwood shows the same pattern. Again, it is highlighted that these problems did not arise from mismanagement. The parties conducting the initial investigations had little guidance as to the quality of the data needed for the RI. Also, the several years that past as these investigations were conducted provided a difficult atmosphere for quality assurance. Many different parties, companies and agencies investigate the site with their own particular interests. The companies interested in investigating for the removal action were not concerned with the usefulness of the data in the RI. Also, the agencies and companies all have a general distrust of each other's data. Efforts are currently underway to combine these removal and remedial investigation efforts so this pattern of insufficient data gathering does not continue. Therefore, it is important for the remediation manager to understand the complications that have arisen in typical Superfund investigations. A strict quality assurance plan outlined in the Sampling and Analysis Plan (SAP) should be implemented at every site. This will ensure that data is properly gathered avoiding repeated work. Implementing strict quality assurance should save time and money by avoiding repetitive work during site investigations.

PART 2: METHODS FOR IMPROVING SITE INVESTIGATIONS

4. SITE SCREENING TECHNOLOGIES (FIELD ANALYTICAL METHODS)

4.1. Introduction

Although subsurface behavior is more readily understood with today's growing expertise in the field, site investigation technologies have not advanced dramatically. However, new site screening technologies, also called Field Analytical Methods (FAMs), are allowing for the more efficient investigation of hazardous waste sites. Innovative site screening tools such as new drilling techniques and portable gas chromatographs have been used recently in the field. There are several advantages to these new screening techniques. First, they are more economical than the standard full scale investigation tools. Also, mobilization and demobilization of site investigation forces is not a primary issue with these field methods. The primary advantage of these technologies is obtaining data almost instantly from the analysis. Also, more samples may be taken over a short period of time. Thus, these technologies allow for a more efficient investigation process. It also helps to avoid the process of constructing wells that often result in non-detects. Although these new technologies are extremely useful, contract laboratory results are still required for QA/QC by the EPA. Thus, these technologies may only be used to pinpoint sampling positions for well construction to obtain certified laboratory results. However, it is believed that using these technologies wisely may reduce the time and cost of a site investigation drastically. Examples of these technologies will be examined in this chapter along with case study analysis to illustrate the cost and time benefits when using FAMs.

4.2.Field Screening Technologies

4.2.1.New Technologies Changing the Investigation Process

The EPA is gradually allowing the use of FAMs to speed the site investigation process. Not only is time saved, but there is also substantial monetary savings. FAMs change the way site investigations are conducted since the results of a contaminant screening may be obtained in minutes as opposed to weeks as required with standard laboratory turnaround. Site sampling teams do not have to be mobilized and re-mobilized and real time sampling decisions may be made from results. To ensure that FAMs provide reliable results, confirmatory analysis must be completed. This is achieved by sending certain samples to the laboratory to confirm the results of the field testing. For instance, at the Norwood site approximately 10% of the samples taken were sent to the CLP. Confirmatory testing will be discussed further when analyzing the use of immunoassay technology in the Grant Gear equipment decontamination work order.

It is important to outline the differences between the two cases illustrated in Figure 9. The typical site investigation has a time consuming loop if data is not sufficient after initial testing. In all cases, re-sampling with site investigations is necessary. Thus, data is never sufficient after initial sampling. Since data analysis with standard CLP turnaround takes 3 to 4 weeks, this loop requires re-mobilizing forces and waiting for results. On the right in Figure 9, the efficiencies gained from using FAMs are evident. If data is not sufficient, re-sampling is needed. However, when using FAMs, re-sampling

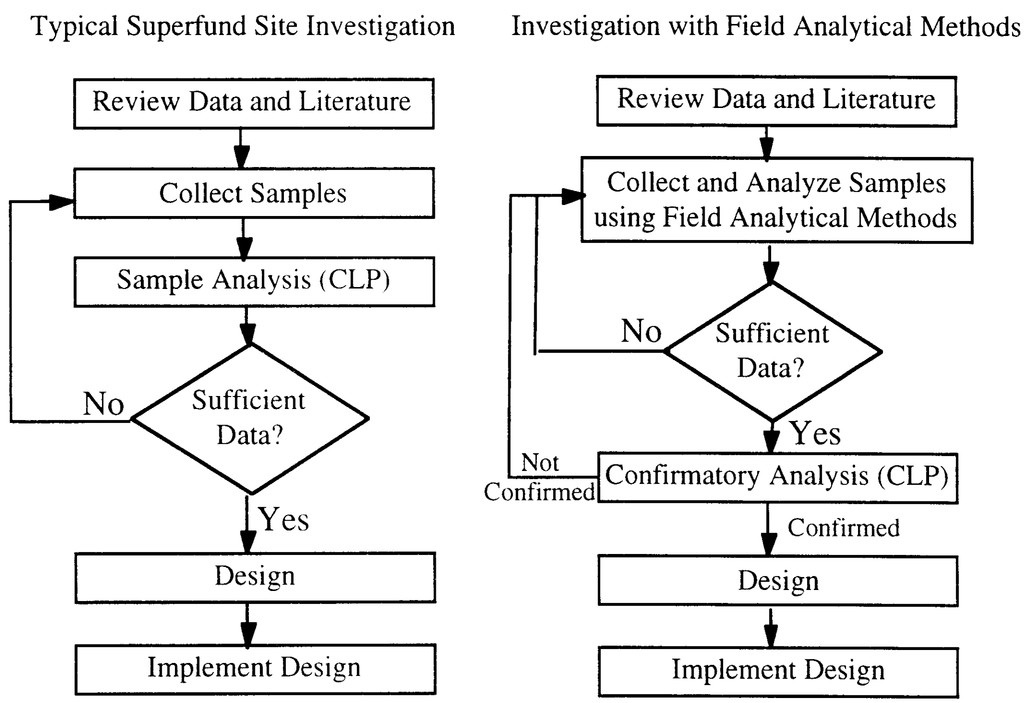

Figure 9: Comparison of Typical CLP Use with the Use of Field Analytical Methods

may be done continuously since testing may be completed in minutes. After sufficient data is collected, confirmatory samples need to be sent through the CLP. This is still required by the EPA. However, with the improving accuracy of FAMs, the field screening results should be confirmed. Only a small percentage should require the repetitive, time consuming loop as in typical investigations. Thus, there is a drastic savings in time and money when using FAMs since on most Superfund sites multiple sampling is very common. As the accuracy of the FAMs improve, even more efficient investigations may be conducted.

4.3. Case Study: The Norwood PCB Superfund Site

The Norwood PCB Superfund site exhibits many of the same characteristics as most major remediation projects. The site has been in the federal remediation process for over ten years. Since the initial report of waste dumping and the ensuing removal action, investigations, designs and treatments have been conducted. Currently major changes are underway at the Norwood site. New soil treatment options are being evaluated with plans to maintain the groundwater treatment portion of the project. Also, remediation efforts have been completed in the Grant Gear building on the site with a delivery order to clean 56 major pieces of machinery and 14 accessories to acceptable levels of PCB contamination. Interesting characteristics of the site include the multiple media affected and the use of innovative assessment technologies. In general, this site is similar to most Superfund actions. It provides valuable insight since new approaches are being attempted in the investigation and contracting efforts.

The Norwood site is a testing ground for one of EPA's innovative assessment technologies. In essence, the Norwood PCB site has been under investigation for such a long period of time, from 1983 to present, that it illustrates both the old methods of conducting site investigations and new attempts to achieve a more cost and time efficient solution. The new site investigation methods which are gaining popularity in the environmental industry are known as Field Analytical Methods (FAMs) or field screening methods. The FAM used at the Norwood site is called immunoassay technology which has been implemented effectively to determine threshold PCB levels. A thorough analysis of the use of this new technology is presented in this case study. Reviewing how the use of these FAMs changes the investigation process, along with a review of the problems and disadvantages of their use, will provide a valuable perspective for the remediation manager. This will aid in the decision-making process when considering the use of FAMs, with almost instantaneous sample analysis, and limiting the use of the Contract Laboratory Program (CLP). A cost comparison between alternatives is also completed showing the potential savings when using screening technologies.

4.3.1. Site Background[15]

The initial trigger for action at the Norwood site was a simple phone call from a resident in the area. On April 1, 1983 the Department of Environmental Quality Engineering (DEQE) now the Department of Environmental Protection (DEP) in the state of Massachusetts was notified of potential contamination at the site. The DEQE completed investigations of several media and PCB contamination was discovered. The site was then transferred to federal jurisdiction since funds were not available on the state level for cleanup. The EPA along with the DEQE then completed a removal action of hot-spots at the site. PCB contamination was particularly high in oil-stained areas of the ground at the site. All areas of PCB contamination above 50 ppm were removed. The remaining contamination was to be cleaned through the remedial or long-term treatment branch of the hazardous waste cleanup process.

A total of 518 tons of contaminated soil was removed during the removal action in 1983. The remaining areas of the site were fenced off and public access was restricted. Thus, the removal action served its purpose to remove the immediate threat to the public. The Norwood PCB site was then proposed for the National Priorities List (NPL) in 1984 and was officially listed in 1986. Thus, the site qualified for federal remedial cleanup moneys under Superfund. Uncharacteristically, the State of Massachusetts completed an Interim Remedial Measure (IRM) in 1986 to limit access to areas on the Grant Gear property. This measure was completed by installing more fencing and capping areas with high PCB concentrations. The caps were installed by using a filter fabric and a six inch thick crushed stone cover. These caps were then used as parking areas; however, the

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[15] Background information obtained from the Remedial Investigation Report for the Norwood PCB Superfund Site prepared by EBASCO Services Incorporated. June, 1989.

stability and seal provided by the cap has caused concern contributing to the need for a new soil cap or remediation.

The Remedial Investigation (RI) at the Norwood site began in 1987 and its designated purpose was to collect sufficient data to quantify public health and environmental risks. Also, the RI supported the evaluation and selection of remedial alternatives. The RI sets forth the reasoning in the Record of Decision (ROD) which outlines the treatment technology to be implemented at the site. The ROD for the Norwood site was signed in 1989 identifying Solvent Extraction as the desired soil treatment technology. This is an innovative treatment technology, used previously on pilot projects, that provides a favorable yet risky alternative to incineration.

4.3.2. Changes at the Norwood Site as of August 1995

Recently, the EPA has decided to change the method of soil treatment that was designated in the ROD[16]. Instead of the innovative Solvent Extraction technology, the ROD may be amended to set out a new alternative treatment which is currently being evaluated. It is believed that a new solution will reduce the risks to the community sufficiently while at the same time providing improved cost efficiency. There were several reasons for this choice. Solvent Extraction is an unproved and risky technology. Also, the initial estimates of the cost of Solvent Extraction were low. Only $29 million was allocated for the soil remediation at the site with a much higher projected cost of $55 million. On the political end, Congress has yet to reauthorize Superfund causing a money shortage for lower priority cleanups such as Norwood. Thus, the EPA decided to look for a new solution instead of increasing funding for the Solvent Extraction. These abrupt decision changes show the rapid evolution of the hazardous waste remediation market with a trend towards more realistic and cost-efficient solutions.

[16] Interview with Major Brian Baker. USACE. July 28, 1995.

4.3.3. *Immunoassay Technology Description*

The immunoassay kits used at the Norwood site to analyze machine and equipment surfaces during decontamination are enzyme immunoassay (EIA) kits[17]. Immunoassay was introduced in 1960 and has been used predominantly in analytical chemistry and endocrinology labs. These immunoassay test kits are even common in the home as seen with simple pregnancy tests. The kits used were purchased from the Millipore Corporation which manufactures one of several EPA licensed immunoassay technologies for PCB testing. These kits allow for qualitative or semiquantitative analysis of PCBs on surfaces. The use of immunoassay technology has increased dramatically in the environmental and food industries recently. This technology is one of the most promising of the new FAMs being introduced into the market because of its selectivity, accuracy, speed, low limits of detection and economy.

Immunoassay uses antibodies derived from animals to detect the desired contaminants. Since these antibodies bind to only the specific contaminant, these tests can measure astonishingly small amounts of a contaminant. However, these antibodies are not easily detected. An extra label compound must be used in conjunction with the antibodies to indicate the level of contaminants. Some of the labels that have been used in the past are radioactive based assays and fluorescent immunoassays.

Currently enzymes are being used more frequently as labeling compounds for many reasons. First, EIA produces a colored end result which indicates the contaminant level. EIA is also safer than other methods since no radioactive elements need to be handled. Finally, EIA has a longer shelf life and simple procedures for analysis compared to other methods. The process for sample analysis is simple and can be performed with little training. Basically, the contaminant is identified by a color change in the test sample. This color is compared to control samples that are prepared at known concentration levels. The amount of color that results is inversely proportional to the

[17] Immunoassay descriptive material was taken from information provided by the Millipore Corporation.

amount of contaminant present. Thus, the darker the tube the smaller the concentration of contaminants. Since this is only a semi-quantitative test, the concentration of the contaminant may only be specified to a level between two of the control samples. If the color is difficult to distinguish with the eye, a spectrophotometer is used. In short, the immunoassay testing is simple and cost efficient contributing to its fast growth as a hazardous waste site characterization tool.

4.3.3.1.Advantages and Disadvantages of Immunoassay Technology

There are several pros and cons of immunoassay technology outlined in Table 1. Constant awareness of the disadvantages of immunoassay technology is vital to the success of a project. Some problems have resulted at the Norwood site from these deficiencies causing cost increases and delays.

Table 1: Advantages and Disadvantages of Immunoassay Technology

Advantages	Disadvantages
• Substantial time and money savings • Sample analysis may be obtained in minutes providing for real-time decision making when re-sampling • Reduced need for remobilization of site investigation forces with nearly instant test results • Samples do not have to be packaged and sent to laboratories reducing the potential for handling problems • Minimal training required for sampling	• Immunoassay results are currently not as accurate as laboratory methods • Interferants easily affect screening results • Immunoassay tests provide concentration levels for one contaminant only • This technology is primarily useful only when a contaminant is well known and consistent throughout the site. If many contaminants are present immunoassay technology is much less efficient.

4.3.4. Previous Investigations in the Grant Gear Building

In 1983, the first investigation of the one story Grant Gear facility was conducted. E.C. Jordan surveyed several different areas in the building. Floors, walls, ceilings and workstations were all sampled by marking off an area of 100 cm^2 and wiping the area with a swab soaked with hexane. The procedure for wiping surfaces was to wipe thoroughly in both directions returning the swab to the bottle several times during the process. Floor samples were found to contain unsatisfactory levels of PCBs along with extremely high levels found on a dusty I-beam flange.

In 1989, the building was investigated further to confirm or deny the results found in 1983. Ten wipe samples were taken in total; six from wall surfaces, three from machine surfaces and one from a locker in the building. Each of the samples was tested for a wide array of PCBs, each only indicating the presence of Aroclor 1254. Contamination levels were found to be significantly less than those in 1983. Proper quality control was also provided with this investigation by providing one field blank and duplicate samples[18]. In 1991, floor samples were taken with concrete borings indicating contamination and in 1993, dust samples were taken along with further wipe samples[19]. Contamination with Aroclor 1254 was again the only PCB found.

In 1994, the primary building investigation related to the Grant Gear equipment decontamination was conducted[20]. The machine surfaces were sampled in preparation for the cleaning of the equipment. 58 samples were taken in total, 4 showing contamination with Aroclor 1260, contrary to earlier investigations. Contamination ranges were from .34 $\mu g/100cm^2$ to 1700 $\mu g/100cm^2$. Samples on the machines were gathered both randomly and systematically. Throughout the room samples were taken randomly to gather a cross section of equipment. However, certain samples were picked on certain machines with high levels of dust and dirt. These areas were expected to have the highest levels of PCB contamination. Samples were taken with the standard 100 cm^2 area marked

[18] Background information on the Grant Gear Facility investigations taken from the Norwood PCB Superfund Site Remedial Investigation Report prepared by EBASCO Services Incorporated. June, 1989

[19] Information obtained from the Draft Work Plan for the Norwood PCB Superfund Site Grant Gear Equipment Decontamination prepared by EBASCO Services Incorporated. November, 1994.

[20] Ibid.

with tape wiping with a hexane soaked gauze pad. This particular investigation and decontamination plan poses many interesting problems. The surfaces of the machines are very inconsistent and some inner compartments need to be sampled. Enclosed inner compartments were found to have little PCB contamination as expected. The highest levels of contamination were found in enclosed areas that were open to ventilation such as engine compartments. This is due to the dust that gathers easily in these areas. Thus, the Grant Gear equipment decontamination poses unique challenges, to clean and sample all of the required abnormal surfaces of machines and equipment.

4.3.5. Delivery Order #9: Project Organization

The delivery order for the Grant Gear equipment decontamination was provided under the Total Environmental Restoration Contract (TERC) won by EBASCO Services Incorporated[21] for the remediation of sites in the New England area. The work plan called

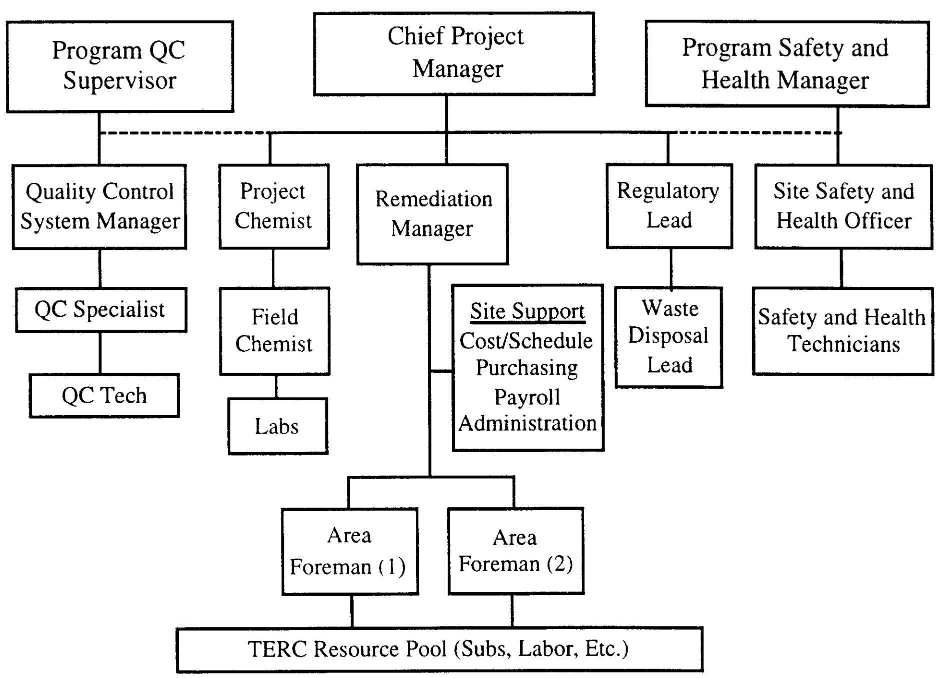

Figure 10: Organizational Chart for the Equipment Decontamination Work Order

[21] EBASCO Services became ENSERCH which was subsequently purchased by the Foster Wheeler Environmental Corporation. The TERC contractor will be referred to as Foster Wheeler in the following case study text.

for the cleaning of 127 pieces of machinery in the Grant Gear building for use at another site. Due to scope changes, only 56 pieces of priority equipment were cleaned. The surfaces of the machinery were sampled to verify that the concentration of PCBs were less than the release limit of $5\mu g/100cm^2$ prescribed in the ROD. This release limit was changed just prior to the initiation of the delivery order to $10\mu g/100cm^2$. The work was scheduled for a period of 40 working days from December 5, 1994 to February 3, 1995. The organization chart proposed by Foster Wheeler illustrates the personnel needed to complete the equipment decontamination work order. Some of the personnel are used in other portions of the work provided for under the TERC contract. The roles of the main players in the project are outlined below and illustrated in Figure 10[22].

Chief Project Manager - Reports to the TERC Project Manager. Is responsible for maintaining the performance standard for execution of the work, including technical project performance, adherence to the schedule, and cost control.

Remediation Manager (RM) - Responsible for execution of the work as described in the work plan. All on-site personnel ultimately report to the RM. The RM is responsible for the training of the craft work force and directing the work force so that the schedule goals are met.

Quality Control System Manager - This duty is shared by two individuals at the Norwood Site. Only one is on site at a time. The QCSM is responsible for the technical quality of the decontamination efforts and works with the RM to ensure efficient completion of the Delivery Order.

Quality Control Specialist - Assists the QCSM in the areas of sampling and sample analysis documentation. The QC specialist coordinates sample analysis with the Delivery Order Chemist.

Site Safety and Health Officer (SSHO) - Is responsible for the overall safety of the operations during the work order. The SSHO is responsible for overseeing the safety technicians and implementing the Site Safety and Health Plan (SSHP).

Project Chemist - Oversees the chemistry objectives for the delivery order. Works closely with the QC System Manager and the Site Safety and Health Manager. Data approval is also a responsibility of the Project Chemist.

[22] Draft Work Plan for the Grant Gear Equipment Decontamination prepared by Foster Wheeler Corporation.

Due to inconsistent surfaces, the sampling of equipment after cleaning poses unique challenges for the remediation team as outlined in the past investigations. Each piece of machinery must receive a "clean" qualification since it will be used in the future at another site. It is important to guarantee this "clean" level since potential liability problems may lie in the future for the contractor , the United States Army Corps of Engineers (USACE) and the EPA. In the work order proposed by Foster Wheeler, the verification qualification and field sampling and analysis plans are outlined. These guidelines outline the exact procedure to be followed to ensure the proper and effective cleaning of equipment. The main criteria for the release of the equipment is a contamination level of $10\mu g/100cm^2$ of total PCBs. First, the cleaning process must be established to obtain this level, second the field sampling procedure is established and third a procedure for verification sampling is established[23].

4.3.6. Use of Immunoassay Technology in the Grant Gear Equipment Decontamination Process

The first aspect of the quality assurance plan is establishing the procedure for cleaning the equipment. How much cleaning will be needed? The immunoassay technology is used to verify the cleaning procedure. First several machines are selected that give an accurate representation of typical machinery in the building. Each machine is cleaned and 30 side-by-side duplicate samples are taken. One of the samples of each 30 is tested by sending the results to an off site CLP. The other duplicate sample is tested with immunoassay technology. The area of the samples for the off site analysis is 100 cm^2 and the area wiped for the immunoassay technology is 200 cm^2. The analysis for the immunoassay is compared to the 10 µg standard provided in the test kit. The cleaning method is performed until 30 immunoassay samples are found with less than $10\mu g/200cm^2$ ($5\mu g/100cm^2$) of PCB contamination. After this is achieved, the second pair of samples are sent to the off-site CLP for analysis by EPA method 8080 which includes

[23] Guidelines for the sampling plan obtained from the Draft Work Plan prepared by Foster Wheeler Corporation

sample extraction and analysis with a gas chromatograph[24]. If all 30 results from the CLP for several machines reveal PCB contamination levels below $10\mu g/100cm^2$, the cleaning method will be considered sufficient. Unfortunately, due to the paint sampling problems this portion of the work plan did not proceed as planned. Slight changes were made to solve the sampling problems and find a consistent cleaning method.

The second step in the process is to outline the field sampling procedures for all of the remaining equipment. This problem is again difficult since there are many different shapes and sizes of equipment. Different machines require different numbers of samples. The breakdown of the number of tests needed for each piece of equipment is outlined below[25]:

- Small Machines 2 Tests
- Medium Machines 5 Tests
- Large Machines 12 Tests

A piece of equipment is tested the appropriate number of times with the immunoassay technology before it is submitted to verification sampling. If any test of the equipment does not fall below the $5\mu g/200cm^2$ limit then the piece is recleaned. The equipment will only be released to verification sampling upon satisfying the immunoassay testing requirement. Guidelines have also been set to address how much of the machine shall be recleaned if test results are above the threshold level. The same fraction of the machine is recleaned as the fraction of samples above the limit. Thus, if two of the twelve samples on a large machine are above the limit, then 1/6 of the machine is recleaned. The Quality Control System Manager (QCSM) is responsible for making the decisions regarding which areas of the machine to re-clean. The QCSM is also responsible for identifying the sampling areas on the machines. Typically, irregular objects are avoided such as screws threads, bolt holes and motor vents. However, an

[24] This is the standard method outlined by the EPA for the analytical testing of PCB samples.

[25] Number of samples derived from using a one-sided tolerance test with estimated machine surface areas.

attempt is still made to cover several different portions of the machine which are suspected of being the dirtiest.

Once the machine appears to be cleaned based on the immunoassay tests, a verification test using EPA laboratory method 8080 is conducted. A 100 cm^2 area is wiped and the piece of equipment is released if the one sample falls below the limit of $10\mu g/100cm^2$ total PCBs. Each piece of machinery is kept on site until the CLP results are returned. If the PCB levels do not exceed the limit the machinery is released with the appropriate documentation. If the contamination still exceeds the $10\mu g/100cm^2$ limit the machine is recleaned, tested with immunoassay again, and retested through the CLP. Release documentation includes such items as what areas were cleaned and sample results from the immunoassay as well as EPA method 8080.

It is important to outline the steps that have been taken to ensure proper sampling and analysis for the Grant Gear equipment decontamination work order. Since the immunoassay technology is somewhat less reliable than EPA method 8080, more samples with the immunoassay have been taken. However, this is not only beneficial for evaluating cleanliness, it is also valuable since immunoassay testing is substantially cheaper than EPA method 8080. Thus, more samples may be taken and cost efficiency is still maintained. The one other step accounting for the decreased accuracy of the immunoassay technology is to sample an area of 200 cm^2 instead of the 100 cm^2 used for EPA method 8080. Thus, the immunoassay test had to meet the more stringent criteria of $5\mu g/100cm^2$. This allows for error on the conservative side and ensures a higher verification rate with the CLP samples than if a $10\mu g/100cm^2$ limit had been used with the immunoassay technology. This conservative approach proved very successful with only one piece of equipment failing the verification analysis.

4.3.6.1. Interesting Findings and Problems with Immunoassay

During a training session with immunoassay technology at the Norwood site there was an unexpected detection of PCBs[26]. The training session was being conducted in a lunchroom in the Grant Gear building and the immunoassay was being tested on the lunchroom table. Much to the surprise of the trainees, the screening test showed that the PCB contamination was above the level of $10\mu g/100cm^2$. The lunchroom was subsequently closed and the EPA was notified. This problem shows the difficulty in cleaning and remediating PCB contaminated sites. The PCBs are very mobile on skin and dusty surfaces exposing employees to potentially harmful situations. Further delineation of exact PCB levels in the lunchroom was completed and measures were taken to prevent the further spread of contamination..

Problems were also encountered with the sampling using the immunoassay technology. Inconsistent results were obtained between immunoassay and laboratory tests when wipe sampling painted surfaces on the machinery. A detailed description of this problem is outlined in the paint sampling problem section at the end of the case study.

4.3.6.2. Cost Breakdown of Equipment Decontamination

Final negotiations were completed between Foster Wheeler and the USACE regarding the costs of the equipment decontamination work order. The tasks were negotiated individually arriving at the final agreement. This is one of the interesting aspects of using a TERC contract. Foster Wheeler was awarded the TERC for the region to remediate the site up to a certain cost limit. Each of the work orders and independent changes are negotiated between the USACE and Foster Wheeler. The final cost breakdown of the equipment decontamination is illustrated in Table 2.

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[26] E-mail message from Major Brian Baker regarding the unexpected detection of PCBs. 12/19/94.

Table 2: Cost Breakdown of Grant Gear Equipment Decontamination (All Costs are Approximate)

Task	Cost
1. Pre-Delivery Order Costs	$150,000
2. Delivery Order Costs	$830,000
3. Field Changes	$120,000
TOTAL	$1,100,000

In total 56 pieces of equipment were cleaned along with 14 accessory pieces. 344 immunoassay samples were taken to verify the cleanliness of the equipment. As outlined previously, a certain number of samples were taken per machine. If any of the tests failed, more samples were taken until all were below threshold levels. Finally, a verification analysis was completed with one EPA Method 8080 test completed for each piece of equipment. Only one off-site verification sample was above the threshold level, an extremely small number considering 56 EPA 8080 tests were taken for the equipment. Thus, the cleaning method and the immunoassay screening tests were performing well. A further breakdown of the tests conducted broken down by machine size is presented in Table 3.

Table 3: Number of Immunoassay Samples by Machine Size

Machine Size	Number of Machines	Number of Initial Samples Per Machine	Percent Machines Requiring Resampling	Total Samples Taken
Small	34	2	44	109
Medium	14	5	36	85
Large	8	12	12	110
Accessory	14	Variable	14	40
			TOTAL	344

The sampling completed on the equipment at the Norwood site was not the only use of this technology. It was also used for verifying the cleaning method, the first stage in the sampling and analysis plan. Also, immunoassay tests were taken for site safety and health reasons. Two other unplanned sets of testing were needed due to problems that were discovered during the delivery order. First, further immunoassay tests were needed to delineate the problems encountered when sampling painted surfaces. Also, more immunoassay tests and EPA Method 8080 verifications were needed to sample the lunchroom that was contaminated above threshold levels. The breakdown of use of the technology along with 8080 verification is shown in Table 4.

Table 4: Number of Immunoassay and 8080 Samples for Delivery Order #9 (Values are Approximate)

Task	Number of Immunoassay Tests	Number of EPA Method 8080 Tests
1. Equipment Sampling	350	60
2. Verification of Cleaning Method	150	60
3. Site Safety and Health	100	10
4. Lunch Room Sampling and Cleaning	180	10
5. Solution of Paint Sampling Problem	100	15
TOTAL	880	155

4.3.6.3. Cost Savings with Immunoassay Technology

A cost comparison between alternatives for site sampling and analysis has been made to gain an understanding of the appropriate uses of the different methods. The first and most likely option, had immunoassay not been available, would be to obtain on-site laboratory facilities in a trailer with a Gas Chromatograph (GC) and other necessary equipment for the extraction of PCBs from samples. The second alternative would have been the analysis of samples off-site through the CLP. This would have been the method used without the advent of on-site laboratories and field screening methods. A cost analysis of these alternatives and a discussion of special considerations is presented. Obviously, it is very difficult to compare the three alternatives for PCB testing. An effort has been made to reduce the cost comparison to the fewest variables possible.

Thus, a dollar value is not given to variables that are difficult to quantify. The assumptions will be outlined with each corresponding cost analysis.

The first cost analysis presented is the use of immunoassay technology as it was implemented at the site. There are several assumptions that simplify the analysis.

- A sampling technician is required for all methods. Also, the TERC project chemist would be responsible for overseeing any of the methods used. Thus, the labor costs for these required personnel have been excluded from the three analyses.
- The quick turnaround of 48-72 hours for lab testing through the CLP was used with a premium cost of $275/sample. This quick turnaround is used in all cost breakdowns. Longer turnaround times would not be cost beneficial due to the time added to the schedule between sampling events. Also, time constraints on this particular delivery order prohibited the standard turnaround of 3-4 weeks for samples.

Table 5: Cost Breakdown of Sampling and Analysis Completed with Immunoassay

Test	Quantity	Unit Price	Cost
Immunoassay	880	25	22000
EPA Method 8080	155	275	42625
		TOTAL	$64625

The second method that may have been used for the PCB testing was to assemble an on-site laboratory consisting of a trailer and a Gas Chromatograph. Also, some extraction equipment and supplies would be needed. The assumptions for this cost analysis are:

- The laboratory would need at least two hired personnel for operation. One is responsible for the extraction and the other for GC analysis.
- Approximately 10% of samples would need to be confirmed through the CLP since quality control is more difficult to achieve with on-site laboratories.
- It is assumed that the laboratory would operate for three months, a best case scenario considering the delivery order.

Table 6: Cost Breakdown Using an On-Site Laboratory[27]

Item	Price	Price/Month	Months	Cost
Mobilization and Demobilization	5000		-	5000
Extraction Personnel		8000	3	24000
GC Analyst		8000	3	24000
Laboratory GC + Extraction Equipment		8000	3	24000
Equipment (Vials, etc.)		1000	3	3000
Confirmatory Analysis (10% of Samples = 60)	275 each			16500
			TOTAL	$96500

The final method that may have been used would be the analysis of all the samples through the off-site CLP. The assumptions for this case are outlined below:

- Approximately 2 samples would have been needed for small machines, 3 for medium and 5 for large. More samples were needed for immunoassay since quality control is difficult with field testing and immunoassay is not as accurate as laboratory methods.
- The number of total samples is estimated with the number of samples taken after the initial wipe added to the expected number of samples taken after a certain percentage of the machines required rewiping.

Table 7: Estimated Number of CLP Samples Needed for Equipment Cleaning

Machine Type	Number of Machines	Samples Needed	Percent Needing Rewipe	Samples Needed After Rewipe	Total Samples Needed
Small	34	2	44	1	83
Medium	14	3	36	2	52
Large	8	5	12	3	43
Accessory	14	2	14	1	30
				TOTAL	208

[27] Estimated costs obtained from Chris Ouellette, Field Laboratory Manager, Aquatec Laboratories

Table 8: Cost Breakdown if Off-Site CLP Analysis Used for All Samples

Task	Number of EPA Method 8080 Tests (Estimated)	Cost
1. Equipment Sampling	208	57200
2. Verification of Cleaning Method	40	11000
3. Site Safety and Health	40	11000
4. Lunch Room Sampling and Cleaning	40	11000
5. Solution of Paint Sampling Problem	0	0
	TOTAL	$90200

There are many special considerations that must be considered beyond the basic cost breakdowns presented above.

- Both the on-site laboratory and using the off-site CLP have sample turnaround times of 48-72 hours. This will inevitably add to the duration and labor cost of the cleaning event compared to using immunoassay. The immunoassay technology has the advantage of providing nearly instant results which allows for minimum project length.
- Problems that were encountered with the immunoassay regarding the sampling of painted surfaces would not have been encountered if the on-site or CLP labs were used.
- There is supposedly little difference in cost between the on-site lab and the off-site lab. However, the on-site lab becomes more cost beneficial as the number of samples increases. The on-site lab would be a more beneficial option had more samples been needed to clean the equipment. The on-site lab has the capacity to analyze approximately 50 samples per day, a capacity not efficiently used on delivery order #9.

The final cost comparison of options is displayed below in Table 9. It is apparent that the immunoassay technology was definitely the most efficient option.

Table 9: Cost Comparison of Sampling and Analysis Methods

Sampling and Analysis Method	Cost
1. Immunoassay Technology	$64625

2. On-Site Laboratory	$96500
3. Off-Site Laboratory Analysis	$90200

The cost savings from the immunoassay as a screening method are obvious, approximately 33% compared to the other methods. This shows the advantages of using these methods as opposed to relying on the laboratories for analysis. Choosing between the on-site lab and off-site lab would have been difficult. If the sampling at the site fills the capacity of the on-site lab, it will definitely be the better option for analysis. However, as seen on delivery order #9 conducted over a period of three months, the on-site lab is not obviously beneficial because enough samples were not taken to take full advantage of on-site facilities. Therefore, the estimated costs of the alternatives gives an idea of the factors leading to a cost efficient site analysis.

In general, site screening tools will be used frequently in the future due to the benefits they provide. However, it is important to consider the limitations of the technology. For instance, an on-site Gas Chromatograph is capable of identifying more than just one type of PCB. Immunoassay, on the other hand, is not capable of measuring other PCBs without conducting an entire separate test. The Grant Gear equipment was contaminated with only Aroclor 1254, so immunoassay was beneficial. However, had more PCBs needed to be delineated, immunoassay may not have been as efficient. These are just some of the factors that must be considered when evaluating alternatives. The pros and cons of the different methods must be considered in detail to determine the best option.

4.3.7. Performance of the TERC Contracting Mechanism

Taking a step back, and looking at the equipment cleaning in general, the TERC provided an efficient contracting mechanism for the delivery order. The TERC is applied at certain sites that have characteristics that are tailored to an environmental restoration contract. The TERC adds to the contracting arsenal used by the USACE and does not replace old methods. The purpose of the TERC is to hire one contractor with a single contract that covers the entire cleanup process. The TERC is also very helpful in addressing the problems with the many changes and uncertainties inherent to hazardous waste projects[28]. The TERC also allows flexibility to address interim actions at a site. Typically, if an interim action is desired with standard contracting, separate contractors must be hired and interface issues become difficult to manage. With the TERC, negotiations are completed with the one contractor and interface issues are diminished. This is precisely what occurred at the Norwood site for delivery order #9. The advantages that the TERC provided are outlined below:

- Delivery order #9 was initiated quickly and was time constrained due to Grant Gear's desire to sell their equipment as soon as possible. The TERC allowed an instant response without preparing detailed bid documents. The delivery order from notification of action to closure was approximately 10 months, a difficult goal for most other contract mechanisms. Separate mobilization efforts for different contractors were also avoided.
- The one contractor approach focuses the responsibility for liability on the one party.
- The TERC allowed for the efficient handling of changes on the project. Further contamination was found in the lunchroom areas and measures were efficiently taken to address them. Had Foster Wheeler not been the sole contractor on the job, the responsibilities for this problem may have been blurred.
- It is advantageous for the contractor to have in-house expertise in all phases of remediation. This helped solve problems in an efficient such as those encountered with the paint sampling.
- The USACE was only responsible for managing one contractor on the project, eliminating interface problems.

The disadvantages with using the TERC on this delivery order are outlined below:

[28] Erickson, Stu. *TERC Adds Weapon to Contracting 'Arsenal'.* District Quarterly, USACE, Missouri River Division.

- More staffing is needed from the USACE to carefully observe costs on the project. The USACE requires more expertise to negotiate all of the costs in the remediation process.
- Negotiations for delivery order costs can be time consuming and require a clearly defined scope of work. The cost efficiency of the delivery order is dependent on the USACE's ability to negotiate costs accurately and effectively.

4.3.8. Should the Equipment have been Cleaned?

Due to changes on delivery order #9, only 56 pieces of equipment were cleaned with 14 accessories. It is difficult to determine if the efforts of the EPA to clean the equipment were worth it. There are many factors that contribute to this decision. First, it has been the EPA's mission to provide a permanent solution to the hazardous waste contamination problems. Thus, it was in the EPA's interest to clean the equipment providing a permanent solution. Also, the equipment in the building was in perfect working condition adding to the desire to clean it. The option to not clean the equipment would leave disposal as the only solution. As far as the EPA is concerned this is an undesirable remedy leading to increased volume in a landfill with a substantial cost for disposal. The debate to clean the equipment typifies debates over hazardous waste treatment in general. How much should be paid for the high price of cleanups to reduce the risks from past contamination? In the view of the author, delivery order #9 was a remediation success. With the use of the innovative contracting mechanism in the TERC, a cost efficient solution was achieved providing perfectly working, clean and safe machinery for return to industry use. Hopefully, these innovative approaches to hazardous waste remediation will be continued alleviating the push to cut back on remediation efforts to reduce costs.

4.3.9. Problems with the Immunoassay Testing

Difficulties have been encountered in the results obtained with the cleaning of the equipment in the Grant Gear building. The equipment is being cleaned with d-limonene spray and paper wipes. This cleaning process has worked well for consistent bare metal surfaces. However, between painted surfaces and bare metal surfaces there have been inconsistent results. Bare metal surfaces have passed the immunoassay screening tests and the confirmatory results have been well below the threshold level of $10\mu g/100cm^2$. However, with the painted surfaces, the immunoassay screening has failed. In fact, even after as many as three cleanings of a painted surface, the surface still did not pass initial immunoassay screening. Also, EPA method 8080 was used on these painted surfaces and the PCB contamination was below the threshold level. Thus, the immunoassay technology and the CLP confirmatory samples contradict each other with the painted surfaces[29]. Such alterations as a painted surface can drastically change results.

The investigators were not sure if the immunoassay technology was the problem with respect to the painted surface inconsistencies. One major difference between the two testing methods is the solvent used in the wipe process. Immunoassay technology uses methanol as a wipe solvent while EPA method 8080 requires hexane as a solvent. There were several possibilities listed below that might have caused the inconsistent results[30]:

- The immunoassay was giving false results because of paint interference with the testing
- Inconsistent field sampling methods
- The methanol used was extracting more of the PCBs than the hexane wipe solvent. This would also indicate that the cleaning was not removing the PCBs from the paint properly.
- The methanol may be extracting more paint; therefore, extracting more PCBs

The site investigation personnel then set out to discover the reason for the inconsistencies in the testing. First, several different tests were used to see if the d-limonene was properly cleaning the painted surface. This involved trying different

[29] All information obtained from the *Interim Analytical Chemistry Report, Immunoassay vs. 8080*. Dated January 19, 1995 from the Foster Wheeler Environmental Corporation to Major Brian Baker, USACE.

[30] Ibid.

solvents and even sanding the surface. There was no substantial difference found unless the paint was removed; thus, the solvent was assumed to be working correctly. Even more specifically, the sampling method was analyzed. Different methods such as using tongs to wipe the sample area or using hand wiping were compared. Some slight differences were encountered; however, these were not believed to have caused the inconsistencies.

More tests were run to delineate the problem with the sampling. The issue of the paint interfering with the test needed to be resolved. Newly painted clean surfaces were tested and the results were below threshold. Finally, several methanol wipes were taken and the solvent was changed to hexane. EPA method 8080 was used on these samples and the results agreed with the above threshold immunoassay screening. Thus, the problem was narrowed down to the solvent being used on the wipe. Methanol, being a more aggressive solvent, was removing more of the PCBs from the paint surface as suspected. One option to remedy the problem is to use the hexane wipes with the immunoassay test. However, the hexane wipes used with the immunoassay technology required drying since hexane is a known interferant to the immunoassay test. When hexane was used with the immunoassay instead of the methanol, the results agreed well with EPA method 8080.

Thus, a typical problem that may occur with the immunoassay screening tests has been outlined. These screening methods do have disadvantages. It is important for the remediation manager to be aware of these potential problems and methods to solve them. In summary, this problem results from the slight difference in the performance of two wipe solvents. Methanol as used in the immunoassay seems to remove more PCBs from the paint than the hexane wipe. Hexane seems to remove only the PCBs from the surface of the paint. The approved solution to the sampling problem was to use hexane with the immunoassay tests. The Millipore Corporation conducted tests and determined that the use of hexane was a viable solution as long as the wipes were dried so the hexane could not interfere with the analysis. This provided for consistent results between laboratory and field samples.

4.4.Case Study - The Central Artery/Tunnel Project

The suppression of interstate 93 in downtown Boston and the building of a third harbor tunnel to Logan Airport is a unique infrastructure project for many reasons. The magnitude of the construction along with the technical challenges qualifies it as a "mega-project". However, on top of these challenges has been the immense effort to obtain approvals from all concerned parties including political, business, environmental and citizen groups. This case study, focusing on the hazardous waste assessment process, addresses only a fraction of the effort required to mitigate environmental concerns on the Central Artery/Tunnel project. The magnitude of the hazardous waste effort demonstrates the challenges presented to the project as a whole.

The Central Artery/Tunnel (CA/T) project is currently the largest infrastructure project in the United States. The Massachusetts Highway Department (MHD) is the state agency responsible for overseeing the delivery of the project. Due to their lack of staffing and expertise with a project of this magnitude, MHD decided to hire an outside consultant to assist with project management. The joint venture of Bechtel and Parsons Brinckerhoff was hired to manage the project along with MHD. The CA/T project has been under extreme political fire and has received massive public scrutiny since the initial idea for the project in the 1970's. The CA/T project is a fasttrack project which is scheduled to be completed in approximately 2005, hopefully dramatically improving the traffic situation in downtown Boston.

Obtaining approvals, permitting and operating within regulations has been a arduous process on the CA/T project. For instance, environmental issues have played a huge role in the development plans for the project. Environmental impacts have been evaluated in many different stages in order to appease such agencies as the EPA and the

United States Army Corps of Engineers. The environmental review process entered its final phase in 1990; however, the debate over the impact on the environment continued to persist. One of the main controversies still to be resolved was the sensitivity of moving all excavated soils to an island in Boston Harbor that was formerly a landfill. These soils posed many problems due to potential contamination and the magnitude of the excavation with 13.5 million cubic yards of soil being transported to the harbor island.[31]

This case study covers just one aspect of the many environmental impacts of the CA/T project. The CA/T project has presented interesting problems for construction contractors and the management team due to hazardous waste that has been encountered on the project right-of-way. The CA/T is being constructed in the heart of downtown Boston and also in South Boston which is a highly industrial urban setting. These properties have been used in the past for other purposes and the former owners have improperly disposed of hazardous waste on the properties. Thus, the management team of Bechtel/Parsons Brinckerhoff (B/PB) has instituted a plan for hazardous waste mitigation. B/PB did not have the in-house expertise to deal with the hazardous waste problem and also did not have the local experience with regulatory authorities to manage this portion of the project effectively. Thus, Camp Dresser & McKee (CDM) was hired as the hazardous waste consultant on the project.

This case study analyzes the site assessment and investigation phase of a construction project where hazardous wastes are present or suspected. These site assessments and the regulations that govern the removal or treatment of hazardous wastes may add substantial length to construction schedules and may also increase costs dramatically. This case study investigates the following:

[31] Luberoff, David. Altshuler, Alan. Baxter, Christie. Mega-Project. A Political History of the Central Artery/Third Harbor Tunnel Project. John F. Kennedy School of Government, Harvard University. May 1993.

1. The process used to identify Oil and Hazardous Materials (OHMs) on the CA/T right-of-way. All phases from site assessment to the comprehensive field investigation will be discussed.
2. The effort to use Field Analytical Methods (FAMs) on the CA/T project. The major issues governing their use will be covered along with an evaluation of their cost and time benefits.

4.4.1. The ROWARS Program

CDM was hired as the Right-of-Way Assessment and Remediation Services (ROWARS) consultant for the CA/T project. The purpose of CDM is to obtain the right-of-way properties along the path of the CA/T project and to ensure that all potential environmental risks are mitigated either before or during construction. The landscape in downtown Boston poses many interesting problems for the ROWARS team. Oil and hazardous materials (OHMs) are the pollutants that have been released in the past at these sites. Also, there are potential releases from underground storage tanks that may pose problems for contractors. The tasks associated with the ROWARS program include:[32]

1. Assisting MHD and B/PB in complying with all federal, state and local regulations regarding the disposal of contaminated soils.
2. Overseeing the characterization, removal and disposal of soils excavated during construction.
3. Provide emergency response for the unanticipated releases of OHMs.
4. Provide services for the appraisal and acquisition of real property along the project right-of-way.

These services have been divided into two major activities for the project, *characterization* and *clearance*. First, the characterization of soils is needed to determine if soils are contaminated, possibly contaminated, or clean. Second, clearance services are provided which involves the stockpiling, transport and disposal of soils to their appropriate sites[33]. Typically, the characterization process is finished before the design

[32] Camp Dresser & McKee, Inc. Characterization Procedures. Central Artery/Tunnel Project, Right of Way Assessment and Remediation Services. May 1993.

[33] Ibid.

packages are completed for bid. However, clearance activities are typically completed during construction while the contractor excavates the soils that have been previously characterized. There have been a few occasions where time critical work packages on the project have been sent to bid without the characterization phase completed. In this case, the contractor has been responsible for both further characterization of soils and clearance activities. In these situations the contractors have hired environmental consultants to assist them with the hazardous waste mitigation effort.

4.4.2. The ROWARS Soil Characterization Activities

This portion of the ROWARS program is analogous to the site investigation phase of a Superfund project, and includes many of the same inefficiencies. For instance, property owners in Boston are responsible for the hazardous wastes disposed of on their property. These strict regulations add to an already inefficient process. Also, the Massachusetts Department of Environmental Protection (MDEP) requires laboratory results to be used for sample analysis which can add significant cost and time to hazardous waste mitigation efforts. These inefficiencies will become apparent as the ROWARS activities are discussed.

The process for soil characterization is divided into two separate activities, *initial assessment* and *field characterization*. This is also similar to a Superfund project with preliminary assessments followed by the remedial investigation, the comprehensive sampling event in the Superfund process.

4.4.3. The Initial Assessment

The first phase of the characterization program is the initial assessment. This is similar to the preliminary assessment stage of the Superfund program. The main purpose of this phase is to identify any significant problems with the parcel of property that is designated as the right-of-way for the CA/T project. These problems are such that would directly affect the acquisition of the property or affect the construction schedule. After the design package is defined, the properties along the right-of-way are assessed. Each parcel undergoes a parcel preview, the first step in the initial assessment process. This involves a quick visit to the site to determine the general size of the parcel and the conditions of abutting properties. This is done only after obtaining site access in coordination with MHD.

Site characterizations may be greatly enhanced by reviewing the past industry activities on the site. This may include a study of the previous buildings on the property and what type of businesses have operated there. The function of the historical and regulatory review is to identify possibilities for the release of OHMs in the past and areas to focus on for site sampling. An attempt will be made to assess the disposal practices of all past owners of the property. In summary, a search of records and regulations will be used to determine the following information[34]:

1. Site history back to 1850 revealing past usage including building footprints and past storage areas.
2. The setting of the parcel, determining past usages of parcels within 200 feet of the right-of-way property.
3. Location of sensitive areas around the right-of-way including schools, hospitals, parks, etc.
4. Permitting history and previous regulatory action.

This information is processed to prepare a strategy for the next step in the process, the site reconnaissance. This step serves to confirm or deny the information researched through the historical and regulatory review. Also, other site characteristics not found during the parcel preview or historical review may be discovered. In summary, the site reconnaissance is used to determine the specific types of hazardous waste to target and where they will most likely be found. This process is followed by the delineation of a sampling and analysis plan for the site. Finally, an initial assessment report (IAR) will be issued which will document potential areas for contamination and possible contaminants that may be found.

[34] Ibid.

4.4.4. The Sampling and Analysis Plan

From the information gathered previously, the site assessment personnel will have a knowledge of the potential areas to target for contamination. Also, the types of contaminants that will likely be found will be known. For all parcels a standard sampling and analysis procedure has been delineated. This procedure is followed with slight alterations to take into account site specificity.

The sampling and analysis plan focuses on two media, soil and groundwater. Each parcel is divided on a 200 foot square grid and there is a minimum of one soil boring taken for each grid section. If contamination is suspected, more borings may be taken for the grid section to increase sampling density. The assumption for this procedure is that soil conditions in the boring are representative of all soils in the grid section. The soil borings will be taken using a drill rig and the samples will be taken within the borehole at 5 foot depth intervals. Each soil sample will be screened using an Organic Vapor Monitor (OVM) to determine if organics are present.

From each boring, there are several different types of samples that will be sent for laboratory analysis. First, an upper composite sample will be taken which is a mixture of the soils taken from the upper fill materials at different depths. Second, an upper discrete sample is taken which is a sample from the upper fill materials with suspected contamination identified by the field screening OVM. If no contamination is present this sample is taken at the groundwater level. Third, a lower discrete sample is taken from the clay at the bottom of the borehole. Extra discrete samples may be taken if contamination is indicated at many depths in the borehole. Finally, samples will be taken for QA/QC including blanks and duplicates[35].

Due to the expense of constructing groundwater monitoring wells, only 20% of the boreholes on the parcels will be completed as monitoring wells. The decision to

[35] Camp Dresser & McKee, Inc. Characterization Procedures. Central Artery/Tunnel Project, Right of Way Assessment and Remediation Services. May 1993.

construct a well will be dependent on the amount of floating product on the water level, a typical indication of contamination. Groundwater samples are then sent to the laboratory for analysis along with QA/QC samples. The final step after the sampling and analysis plan is to draft an Initial Assessment Report (IAR) for each parcel. This is the plan to be followed for the field characterization phase of the site investigation.

4.4.5. Field Characterization

This is the second major phase of the characterization of a parcel on the CA/T right-of-way. The purpose of this portion of the site investigation is to implement the sampling and analysis plan that was delineated in the initial assessment. There are several details that must be outlined for this phase beyond the implementation. After completing the sampling and analysis plan, the samples will have to be analyzed through the laboratory for a wide spectrum of possible contaminants. Also, the characterization is not completed until the impacts of the contamination on the construction schedule are determined. Finally, the field characterization phase ends with the identification of future activities for treatment of the soil or groundwater. Three alternatives exist: further characterization, future clearance or no action. The data collected for the field characterization will be used for the following purposes on the CA/T project[36]:

1. Determining the areas of soils which are not suitable for project reuse or disposal on Spectacle Island due to concentrations of OHMs. Thus, the soils requiring special disposal or treatment are to be identified.
2. Determining which soils may have health impacts for the area surrounding the construction parcel. These soils will require special efforts so that public health is protected.
3. Determining the location of contaminated groundwater. The groundwater may be contaminated with floating product, DNAPL, LNAPL, or dissolved contaminants.

The characterization phase of the site investigation requires flexibility. This is in preparation for contingencies that may be found on the site as characterization activities proceed. For instance, contingency boreholes may need to be made if further

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[36] Ibid.

contamination is found while working in the field. An allowance is made in the drilling contracts for these contingency borings. Also, additional groundwater monitoring wells may have to be installed due to the same conditions. Laboratory tests for such contaminants as PCBs and TCLP may be required if records suggest possible contamination or if on-site activities indicate the need. Finally, the standard turn-around-time for laboratory samples on the central artery is 3 weeks; however, accelerated turn-around-times may be requested. This may be needed for time constrained projects.

The administrative requirements for conducting the field characterization effort are outlined specifically in the sampling and analysis plan. The following items will be required as a minimum for each parcel[37]:

1. Quality assurance and quality control procedures.
2. Health and safety plan.
3. Documentation and chain of custody procedures.
4. Procedures for equipment use and maintenance.
5. Laboratory analysis methods and procedures for coordinating with the laboratories.

The final steps in the characterization procedures are to analyze the results obtained from the laboratory analysis and to complete the characterization report. If areas are found to have contamination that exceeds safe levels, then a clearance study will be completed to evaluate methods for remediation. These studies will involve determining the cost and time benefits of remedial alternatives for the soil. If the contaminated soils or groundwater affect areas around the parcel on the right-of-way, measures will be taken to mitigate the spread of the contamination to surrounding areas. After these methods are determined the final characterization report for the parcel will be completed. The report will include documentation on the following: field activities, areas of high OHM concentrations, possible suggested actions such as emergency response or further clearance studies, and all analysis data.

[37] Ibid.

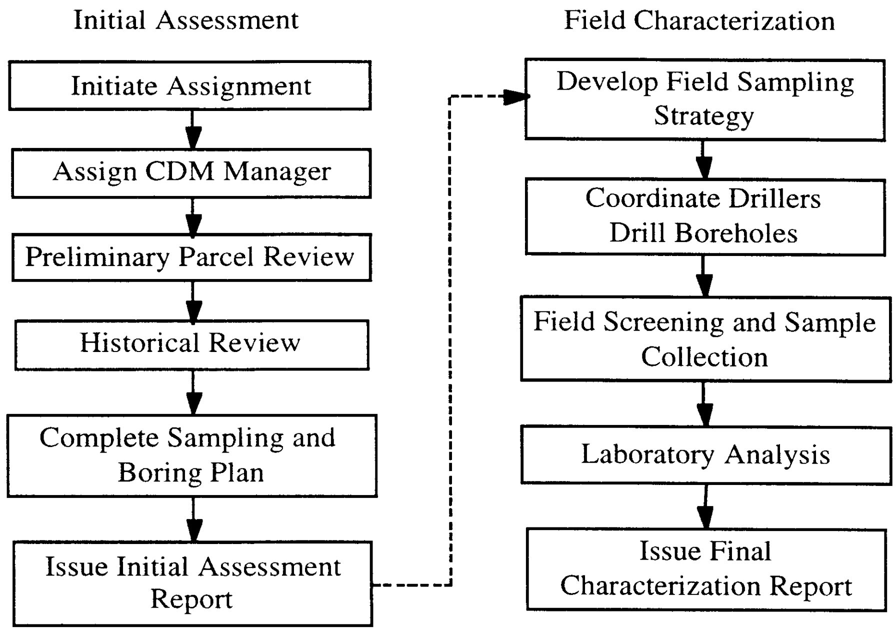

Figure 11: Summary of Initial Assessment and Characterization Activities

After both the initial assessment and the field characterization are completed, the management team of the CA/T project has a thorough knowledge of the contaminants present for the parcel in the right-of-way. If there are no OHMs present, the bid package will reflect normal reuse of the soil or transport to Spectacle Island in Boston Harbor. If the soils are contaminated above safe levels, further clearance studies will be completed to evaluate remedial alternatives. A summary of the activities for each phase of the site investigation on the CA/T project is displayed in Figure 11.

4.4.6. Field Analytical Methods (FAMs) on the CA/T Project

The site investigation process that was discussed for the CA/T project is analogous to the Superfund site investigation process. Thus, the same inefficiencies exist. The analytical methods used on the CA/T project are very expensive and time consuming for many reasons. First, laboratory analysis is very costly and turnaround times for samples are typically 3 weeks which adds to the overall schedule of sampling activities. However, the laboratory analysis is required by the Massachusetts DEP for data quality assurance. CDM has made an effort to streamline the characterization process with Field Analytical Methods (FAMs) similar to the process used at the Norwood site. However, the effective use of the technologies has been limited mainly due to regulator opposition and the risk averse environment on the project. This portion of the case study discusses efforts to use FAMs on the CA/T project and their cost and time benefits. The use of Organic Vapor Meters along with the intended use of immunoassay technology and XRF Spectroscopy is discussed. Also, the decision-making process behind their use is outlined. Finally, an evaluation of the FAM's future use potential on the project is given.

4.4.6.1.Organic Vapor Monitor (OVM)

There are many different names for this type of instrument such as the Photoionization Detectors (PID) or the HNU meter. Also, a Flame Ionization Detector (FID) may be used with slightly different procedures. The OVM is the crudest form of field screening tool which has been used for many years during hazardous soil characterization. Unfortunately, this instrument does not give an indication of the type of organic present. However, it does indicate the presence of organics and gives a general correlation to concentration levels. The advantages of the OVM are: highly portable, ease of use requiring little training, relatively inexpensive (around $5000), and durable. The main disadvantage is that the detectors do not designate contaminants specifically[38]. These instruments are commonly used in conjunction with laboratory Gas Chromatographs (GC) for the complete analysis of organic contamination.

On the CA/T project, these crude portable screening tools allow the sampling team to specify certain samples for analysis. Thus, if a soil sample is taken and organics are detected with the OVM, this sample will be sent for laboratory analysis. This avoids the non-detects that are typical with laboratory sampling. The number of non-detects will be limited with the OVM avoiding excess laboratory costs. The OVMs used on the CA/T project are used to detect the trace gases from volatile organics. Each of the instruments must be calibrated before use to a certain standard and the instruments are

[38] United States Environmental Protection Agency. Subsurface Characterization and Monitoring Techniques: A Desk Reference Guide. Volume II. EPA/625/R-93/003b. May 1993. P. 10-24.

operated by CDM personnel on the site[39]. If procedures are followed properly, trace amounts of contaminant may be detected providing an initial indication of contaminant levels. This screening tool is also valuable for site safety on construction projects indicating the presence of contamination in an inexpensive manner. This will help contractors avoid the liability issues of unexpected employee exposure[40].

4.4.6.2.Further FAM Use - Immunoassay and XRF Spectroscopy[41]

These innovative methods are gaining popularity for field use on typical construction projects and also on remediation projects. The federal regulatory authorities are beginning to loosen the restrictions for the use of these methods. As they become more accurate and with proper quality assurance, these field methods can be both inexpensive and time efficient. However, on the CA/T project, the state regulators have been less cooperative. The CA/T project decided to investigate the feasibility of these field methods in 1993. CDM decided that time and money could be saved if alternative methods to laboratory testing were investigated. CDM proceeded by evaluating the quality that could be obtained by alternative laboratory analytical methods and alternative field methods. This analysis focuses on the field methods that were evaluated for use on the CA/T project. Unfortunately, the field characterization portion of the ROWARS contract had been nearly completed before the field methods were evaluated. Thus, little use has been made of these innovative methods for field characterization. However, they have been used on a limited basis during clearance studies which are the more thorough investigations of contaminated areas to evaluate remedial alternatives. Also, they have been used during construction to evaluate soil contamination.

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[39] Camp Dresser & McKee, Inc. Sampling and Analysis Procedures. Central Artery/Tunnel Project, Right of Way Assessment and Remediation Services. April 1993.

[40] Watton, Dan. Construction Business Review. "Being Prepared for Unexpected Hazardous Waste". May/June, 1994.

[41] Camp Dresser & McKee, Inc. Evaluation of Alternative Analytical Techniques for the Quantification of TPH, PAHs and Metals in Soil. Central Artery/Tunnel Project. September 1993

CDM evaluated the field methods for detecting Total Petroleum Hydrocarbons (TPH), Polycyclic Aromatic Hydrocarbons (PAH) and metals (particularly lead). These methods have to be evaluated before their use to ensure that they will provide data of the necessary quality. With these methods, analytical turnaround time is expedited and analytical costs are reduced. The field screening promised almost instantaneous results in the field which would be extremely valuable for clearance studies and construction soil testing. Two different types of methods were evaluated. Immunoassay kits were tested for effectiveness detecting TPH and PAH. Also, X-ray Fluorescence Spectroscopy (XRF) was tested on metals in project soils.

The immunoassay kits for the detection of TPH and PAH have been obtained from the ENSYS corporation. Kits are also available from firms such as Millipore. CDM used soils that were collected in the D012A design package as samples for the evaluation of the immunoassay kits for detecting PAHs. These soils were tested with the PAH RISc Immunoassay test and compared to the standard laboratory method of testing, gas chromatography with mass spectrometry. Also, soil samples were tested for TPH with the Petro RISc Immunoassay test. These soil samples were also compared to the standard laboratory results. Each immunoassay test requires a 10 gram sample of soil and approximately 20 minutes of time for analysis. The concentration of the contaminant is indicated by a color change in the test as described in the Norwood PCB Superfund Site case study. The tests only indicate if the contaminate is concentrated above or below a threshold level. No absolute numerical value results from the test.

The results of the immunoassay tests compared to the standard laboratory method were very promising for both PAH and TPH samples. The TPH immunoassay performed extremely well with only one of twelve results inconsistent with the standard laboratory method. Thus, the TPH tests were approximately 91% accurate. Also, the PAH immunoassay test performed well with all twelve samples consistent with the laboratory method. CDM then made conclusions from their testing. The TPH immunoassays were to be used with duplicate samples taken on every eleventh sample due to the 91% success rate. Also, CDM recommends that the PAH tests have duplicates for every thirteenth sample to be conservative since the actual failure rate is unknown. CDM also suggested that other immunoassay kits from different manufacturers be evaluated for ease of use if they function similarly.

The recommendations for implementation of these immunoassay kits still reflect the conservative nature of sampling procedures on construction projects and Superfund sites. The accuracy of these methods is still doubted and immunoassay kits do not give an absolute numerical indication of contaminant levels. Thus, CDM has not recommended the use of immunoassay during field characterization activities. At this phase in the investigation it is still important to know absolute values of contamination which can only be obtained at this time through laboratory methods. However, CDM has recommended the use of immunoassay with clearance studies and stockpile testing during construction. Immunoassay is used during removal activities and the results are confirmed if the tests indicate contamination. This will save time and money since the laboratory is used only sporadically. The confirmatory samples will be used approximately 20% of the time until the confidence of the regulators increases. In the future hopefully only 10% of the samples will have to be confirmed through the laboratories. CDM believes that these methods will provide for time and cost savings while maintaining the quality of the data needed[42].

The second FAM evaluated on the CA/T project was XRF spectroscopy for the detection of metals in project soils, another potential major contaminant. There have been several design areas identified with possible TCLP-lead contamination and XRF presents a method to streamline the clearance activities in these areas. Two different types of XRF tools were evaluated including a hand held and fixed base model. The fixed base

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[42] Camp Dresser & McKee, Inc. Evaluation of Alternative Analytical Techniques for the Quantification of TPH, PAHs and Metals in Soil. Central Artery/Tunnel Project. September 1993.

version would be used on site in a trailer for analysis. Analytical results for both the fixed base and hand held models were compared with laboratory methods to evaluate the effectiveness of these tools to ensure proper data quality. In addition to lead detection, these XRF spectrometers can detect antimony, barium, cadmium, calcium, chromium, copper, iron, manganese, mercury, nickel and zinc. Unfortunately, XRF cannot detect beryllium[43].

A total of 40 soil samples were collected from the D001A design package and were analyzed for the study. One potential problem arises when using this type of portable method. In the field, soil samples will be unprepared when they are tested which adds some inconsistency to results. In laboratory testing, these samples are dried and prepared by shaking the samples providing a more even distribution of contamination. Samples for the fixed base method and the hand held model were tested by both preparing samples and leaving duplicates unprepared. It was determined that both hand held and fixed-base XRF spectrometers be used for determining the levels of lead in clearance soils. The field methods were determined to provide sufficient accuracy and precision for the proper evaluation of the soils[44]. There was also a solid correlation between the results of the unprepared samples and the prepared samples. Thus, the samples do not have to be prepared in the field. Finally, the XRF spectrometer should be used for specific metals only if the concentrations are well above the detection limits for the instruments. While lead provided reliable results, other metals were not as detectable if not well above the detection limits of the instrument.

4.4.6.3. Use of Field Methods on the CA/T Project - Cost and Time Savings

As stated previously, the use of FAMs on the CA/T project has been very limited. The reasons for this are many. First, the MDEP, the regulatory authority

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[43] Ibid.

[44] Camp Dresser & McKee, Inc. Evaluation of Alternative Analytical Techniques for the Quantification of TPH, PAHs and Metals in Soil. Central Artery/Tunnel Project. September 1993.

overseeing the project, has not been satisfied with the results of the comparison of the field screening with laboratory methods. The MDEP feels that enough comparison has not been completed to fully understand the methods. This attitude is contradictory to the Norwood project; however, PCBs were the only contaminant being analyzed at Norwood. PCBs have been regulated for a long period of time and the field analysis methods for PCBs are the most fully understood and tested. Also, Norwood was designated as a test site for innovative technologies. Another reason why the MDEP opposes immunoassay use is that the method does not have sufficient detection limits for some MDEP standards. Included with this is the specificity of immunoassay technology. Since contaminants such as TPH are diverse and result from many different types of fuels the accuracy of immunoassay has been questioned[45]. Immunoassay has only been trusted where contaminants are well known and consistent. The use of XRF was another issue entirely. The hand-held models were not trusted by the MDEP due to the inherent error with outdoor testing and human error. The fixed base trailer models were accepted; however, this method was not cost efficient compared to the laboratory since only limited sampling was needed[46].

Several different firms have presented their ideas for field analysis to representatives from the CA/T project. Stephen Greason, from Urban Contamination, specializes in on-site testing in urban areas. Urban Contamination agrees with the alternative field techniques that CDM proposed including immunoassay technology for TPH, PAH and PCBs. Also, it was suggested that XRF be used for the evaluation of metals on the project[47]. The evaluation of TPH contamination is approximately \$100/sample for laboratory analysis compared to \$30/sample for immunoassay results. Similar cost savings will be found for PAH analysis. XRF analysis savings depends on

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[45] Interview with Mike Miller, Camp Dresser & McKee, Inc. Project Chemist.

[46] Interview with Andrea Sewall, Camp Dresser & McKee, Inc. Managed the Evaluation of Alternative Field Techniques.

[47] Interview with Stephen Greason of Urban Contamination.

the use of the equipment. Typically, XRF spectrometers cost around $40,000/machine. With analytical costs of $100/sample this equipment becomes cost effective in a short period of time. Thus, outside professionals agree that these methods are effective. With proper quality assurance, the risks of using them may be reduced successfully.

Several other problems with using field methods on the Artery project are due to the limited resources of the MDEP. For instance, MDEP does not have sufficient personnel on the project to oversee the implementation of new risky methods. Also, it seems that the regulators fear that the new methods may give different results than found in the past when parcels were initially characterized. This would create substantial problems. In summary the regulators are risk averse and conservative. The use of FAMs may only increase with time and changed attitudes.

4.5.Conclusions

Unfortunately, some of the disadvantages of the field methods in conjunction with the risk averse and conservative nature of the regulators has limited the use of innovative field methods on the CA/T project. Immunoassay has been the only method used on a very limited basis. For instance, a fuel spill on the project was evaluated with immunoassay technology. However, in this case the contaminant was known and very specific. Immunoassay was perfect for this situation. However, innovative thinkers in the industry believe that all of these methods may be used effectively and save time and money. If proper quality assurance procedures are used with laboratory confirmation samples the accuracy of the methods can be guaranteed. It is recommended that these methods be pursued for all hazardous waste cleanup projects. The Norwood case study is an example of proper use of innovative technologies. Similar approaches should be used for all projects by defining a sampling and analysis plan that accounts for the potential risks of the field methods. As regulators accept these methods over time, an advantage will be gained by those who understand their use.

5. DEVELOPING A CONCEPTUAL SUBSURFACE HYDROGEOLOGIC MODEL

5.1.Introduction

Developing a complete subsurface characterization before installing monitoring wells has proven to be an underutilized tool during site investigations on groundwater contaminated sites. Few Superfund sites have been fully characterized by collecting complete geologic and geotechnical information[48]. Thus, the sites have been investigated before the complete hydrogeologic behavior is understood. This has caused a substantial increase in the cost of remedial investigations since the investigations have evolved to "plume chases". The EPA recommended approach for the RI is to define the area, extent and magnitude of contamination. Unfortunately, this is only the end goal. This approach defined by the EPA is called "plume delineation" which entails many drilling, sampling and analysis events to develop the database needed for risk assessments and the determination of appropriate remedial actions. It has become apparent in the last few

[48] Sara, Martin N. Standard Handbook for Solid and Hazardous Waste Facility Assessments. Lewis Publishers. 1994.

years that this is not the most efficient method for the delineation of contaminants in the groundwater.

A Superfund site may be better understood by examining the site completely, performing geophysical surveys, and drilling stratigraphic boreholes. This data may be collected and used along with numerical modeling to obtain a complete understanding of the subsurface behavior at a site. This information is then used to optimally install monitoring wells for field or laboratory analysis. As with site screening technologies, this process will avoid repetitive testing events with long analytical turnover times. An overview of the theory behind understanding the behavior of groundwater in the subsurface is reviewed in this chapter. A case study of the Massachusetts Military Reservation is also discussed to analyze attempts that have been made to understand the subsurface. It is found that developing a conceptual model in conjunction with numerical modeling allows for the unique behavior of groundwater plumes to be understood.

5.1.1. From "Saturation Sampling" to "Smart Sampling"

The typical RI begins by reviewing background data and obtaining an idea of the site characteristics from historical activities at the site. Monitoring well positions are then determined from the general knowledge of site conditions derived from topographical maps, aerial photographs, historical accounts of disposal methods and a variable amount of technical site data from preliminary assessments. Unfortunately, in some cases where a high degree of technical data is available, this is also not used due to quality assurance and documentation requirements. In almost all cases, this initial event shows that the contaminant has surpassed the bounds of the sampling or the sampling event was not thorough enough for the production of concentration gradients. More sampling events are then needed and a "plume chase" results.

The alternative method is to understand the geology and the movement of the groundwater first. This focuses the investigation and will streamline the process. Ideally, environmental sampling would be postponed until the hydrogeologic flow paths and flow mechanisms are adequately understood[50]. The new method will involve a review of all site historical data including aerial photographs and topographical maps. A geophysical survey is conducted, stratigraphic boreholes are drilled and piezometers are installed for the measurement of heads and groundwater levels. Also, the measurement of soil parameters is completed to allow for the prediction of the rate and extent of contaminant flow. Numerical modeling is also used to assist with the understanding of the behavior of the subsurface. Predictions may be made with this data to outline an efficient sampling and analysis plan. The illustration of this ideal model is shown in Figure 13 contrasted with the "plume delineation method" seen in Figure 12.

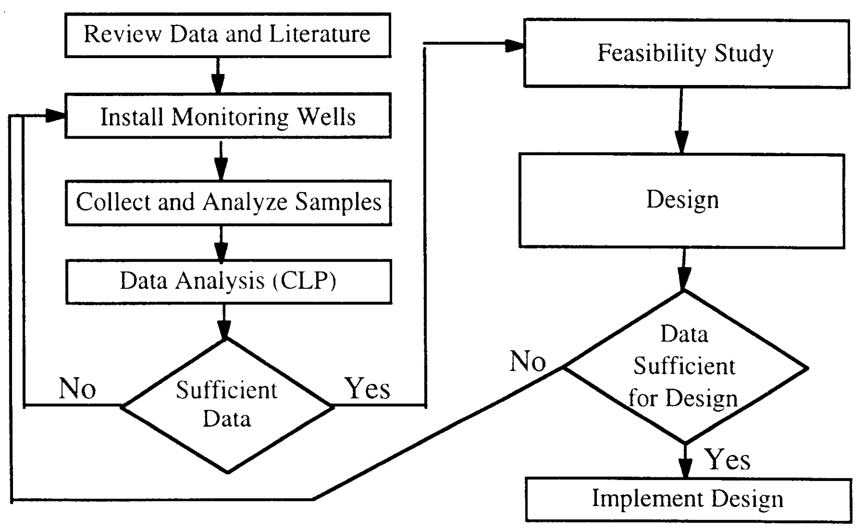

Figure 12: Plume Delineation Method[49]

[49] Sara, Martin N. Standard Handbook for Solid and Hazardous Waste Facility Assessments. Lewis Publishers. 1994.

[50] Sara, Martin N. Standard Handbook for Solid and Hazardous Waste Facility Assessments. Lewis Publishers. 1994.

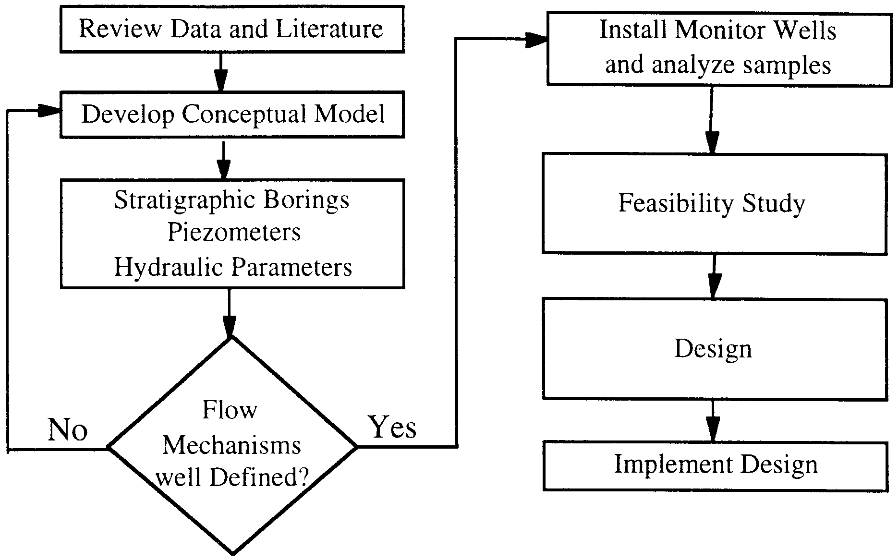

Figure 13: The Conceptual Analysis Method[51]

There are many steps that will lead to the successful use of the conceptual subsurface model. For instance, properly targeting the areas of potential contamination allows the model to be developed more effectively. This process may be broken down into seven basic steps outlined below[52]:

1. **Locate important site features on a topographic map surface**: These features may include such site characteristics as former disposal areas, stained soils, pipelines or underground storage tanks. Also, areas of discharge or recharge into the groundwater aquifer should be displayed on the map.
2. **Analyze cross sections of the site to enhance the conceptual model**: Geologic soil borings should be taken from the area to allow cross sections of the subsurface to be constructed and reviewed around all important site features outlined in step 1. At this point the geology of the subsurface is more clearly understood with respect to the important areas of potential contamination.
3. **Use flow nets and computer models to define likely groundwater movements**: This step adds the groundwater movement to the developing model. By using piezometric heads, the velocity and direction of the groundwater flow may be calculated. Also, with the assistance of computer modeling, a more detailed analysis may be made. At this point, the geology, main sources of contamination and their relationship to groundwater flow are understood.

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[51] Sara, Martin N. Standard Handbook for Solid and Hazardous Waste Facility Assessments. Lewis Publishers. 1994.

[52] Ibid.

4. **Select target areas for monitoring**: Outline the areas below the contamination sources where the contamination has most likely spread.
5. **Evaluate target contaminants and background water quality**: Data should be obtained from the contaminant areas with samples to indicate the contaminants to target for further sampling. Also, a background sample from upstream groundwater flow should be analyzed to determine the contaminants in the groundwater naturally.
6. **Locate assessment wells**: Choose the area that is deemed contaminated from the conceptual model and install monitoring wells to test for contaminants. The flow nets, and flow paths determined from the computer model or calculations outline the areas for sampling. Sampling should start from the facility downstream to the estimated boundaries of the plume.
7. **Estimate plume and complete program**: The monitoring wells will indicate contamination as expected if the conceptual model is used properly. Thus, the extent of the plume will be determined or will be easy to estimate from the data obtained. Once this is achieved, the results may be passed to the remedial designers.

5.1.2. Considerations for Conceptual Model Development

The ideas and process behind developing a conceptual model are simple on the surface; however, several key success factors need to be considered. The development should be directed by a qualified hydrogeologist who has a thorough understanding of subsurface behavior and is versatile with analysis tools such as computer modeling. Also, the need to continually develop this model with sampling results is essential for the proper use of the model in the design and with the remedial action. The model must be refined at each step in the Superfund process so it is effective. If these factors are taken into account, the conceptual model will prove to be a valuable tool.

5.1.3. Advantages

This method of understanding the subsurface behavior has many advantages in the RI phase along with downstream benefits. As stated previously, understanding the subsurface will allow for the more accurate placement of expensive monitoring wells. This will avoid the "saturation sampling" pattern that has evolved at many Superfund sites. What results is a "smart sampling" plan where wells are placed strategically to determine the rate and extent of the plume. The main advantages of this are time savings if resampling events are avoided and monetary savings with fewer wells being installed. Also, many further sampling events have been needed in the design phase to understand the subsurface behavior. This second sampling stage should not be needed if the conceptual model is developed from the outset. In summary, understanding the subsurface behavior is needed for design, so complete this effort before the RI phase to aid both phases. This effort should be completed just once in the process with the design and investigation teams collaborating.

5.2.Case Study - The Massachusetts Military Reservation

The release of Oil and Hazardous Materials (OHMs) is one of the most pressing problems at many of the military bases that are now being decommissioned in the United States. At Otis Air Force Base, also called the Massachusetts Military Reservation (MMR), there are multiple plumes of contaminated groundwater that are currently endangering the public water supply and also many natural ponds in the Cape Cod area. The sources of contamination at the site are varied including motor pools, sewage disposal, training areas and drainage structures. There are currently ten major plumes of groundwater contamination that need to be controlled with several of them already migrating off the MMR property.

Otis Air Force Base is located on Cape Cod in Massachusetts, primarily a residential area. The aquifer that serves the Cape Cod region has been designated a sole source aquifer since it is only recharged through precipitation. However, this is the only water available to Cape Cod residents since the aquifer provides 100% of the water supply through private wells and municipal wells. The area that has been affected by the contaminated plumes is large and will affect more and more of the aquifer as time passes. Obviously, the containment of these plumes is crucial. With each passing year, 211 acres more land surface will be underlain by contaminated groundwater. The groundwater remediation effort is proceeding with the Installation Restoration Program (IRP) that has been instituted at the site. Eventually, all of the groundwater plumes will be contained by some remedial measure. Currently, pump and treat systems have been implemented to stop the advancement of one of the plumes with others to follow shortly with the accelerated cleanup plan. Hopefully, these efforts will stop the loss of potable water in the area[53].

5.2.1. Understanding the Hydrogeology at the Site

At the MMR, there have been exhaustive efforts to understand the subsurface behavior to assure effective groundwater remediation. For pump and treat design it is important to understand the hydrogeology of the site completely. At MMR this has been completed in two stages. First, the geology and groundwater flow in the entire Cape Cod region was researched thoroughly. Second, the more focused understanding of the subsurface was completed for each plume area. This case study is completed by looking at several different aspects of the plume contamination at the MMR. First, the Ashumet Valley plume will be discussed along with the development of a conceptual model for groundwater flow. The second part of the case study focuses on the use of computer modeling as a tool for understanding subsurface behavior. A chemical spill is analyzed showing what conclusions may be drawn from the computer model along with implications for the understanding of the hydrogeology. This plume is very interesting since it is very long and very narrow which is unexpected with sediments found in the Cape Cod region. The computer model suggests some reasons for this unique behavior. In all, the MMR has been studied in great detail contributing to the effective remediation of the site.

5.2.2. The Geology and Hydrogeology of the Cape Cod Region

The first step in understanding the subsurface behavior is to evaluate the geology in the region and the groundwater flow characteristics. The site was studied to evaluate the origins of the soils in the region and their characteristics. In general, the sediments in

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[53] Plume Response Plan. Prepared for the Plume Management Process Action Team. June 1994. Massachusetts Military Reservation.

the Cape Cod region are relatively uniform; however, in some cases heterogeneities do occur. Some soils were found to be stratified which influences the hydraulic conductivities in the horizontal and vertical directions. Borings were taken to understand the geologic makeup of the region.

The Cape Cod aquifer was determined to be a sole source aquifer recharged solely by precipitation. This aquifer underlies all areas on Cape Cod including the MMR. The highest point of the water table was determined to lie beneath the northern portion of the MMR. From simple flow mechanics, this means that the flow is directed radially outward from this point. The depth of the aquifer is hard to determine for this site since there is a gradual transition from coarse to fine-grained sediments as depth increases. Thus, there is no layer that is considered impermeable forming the bottom of the aquifer. There are also many kettle hole ponds in the region where the ground surface lies below the groundwater table. These ponds directly affect the direction of groundwater flow in their vicinity. Many of these same ponds are currently threatened by the contaminated plumes.

Thorough studies were also completed determining the horizontal velocity of groundwater movement through the different types of sediments in the region. Velocities range from 3.4 ft/day in the coarse sediments to .6 ft/day through some of the finer sediments. These factors are critical for determining the rate at which the plume is moving. Also, piezometers were used to obtain flow directions in different areas and around the ponds. Also, simple tracer tests were completed where harmless chemicals are purposely inserted into the groundwater to determine flow velocity and direction. As it turns out, the tracer chemicals do not flow entirely in the horizontal direction. This is due to the recharge of the aquifer with precipitation driving the contaminants further into the aquifer. Thus, the depth of the plumes gradually increase as movement progresses.

The local groundwater flow regime may be summarized as follows[54]:

1. The primary aquifer material at MMR is a well sorted sand and gravel sediment mixture.
2. Groundwater flow is generally southward with flow velocities ranging from 1 ft./day to 3 ft./day.

5.2.3. Developing the Conceptual Model for the Ashumet Valley Plume

The effluent produced from treated wastewater throughout the United States has been disposed of in the past by discharging it back into the ground. The effluent is drained onto sand fields which allow for rapid infiltration into the groundwater. At Otis Air Force Base, effluent has been discharged onto 12 acres of sand beds near the wastewater treatment plant on the base. At first, this method was deemed safe; however, the environmental safety of this method has been questioned. At other sites in the United States, this type of waste disposal has caused groundwater contamination and this possibility needed to be determined for the Otis Air Force Base Sewage Treatment Facility. Unfortunately, all of the drinking water in the area is obtained from the same aquifer where effluent was being discharged. The chance that this has adversely affected water quality is likely. The rate and extent of the likely contamination needed to be defined at the site[55]. In this case a comprehensive effort was made to understand the subsurface behavior.

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[54] Ibid.

[55] LeBlanc, Dennis R. "Sewage Plume in Sand and Gravel Aquifer, Cape Cod, Massachusetts. U.S. Geological Survey Water-Supply Paper 2218. 1985.

The first step in understanding the contamination at the site was to review all available data. The quantities of effluent drained on the sand beds were estimated and the potential contaminants were determined. Topographic maps for the site had already been developed with the many studies completed in the region. Borings were then taken in the suspected plume area which gave a representation of the cross section through which the groundwater was flowing. An illustration of this cross section showing the boring points is shown in Figure 14.

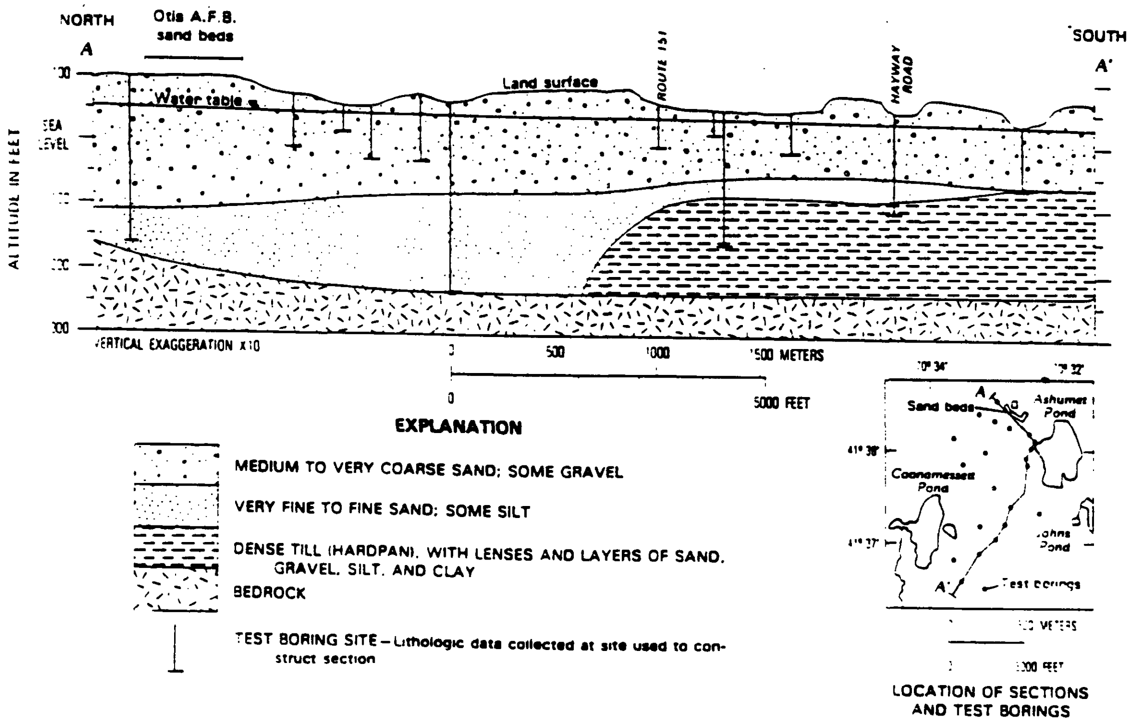

Figure 14: Geology and Hydrogeologic Units for the Ashumet Valley Plume[56]

For this case several test borings were taken that delineated the stratigraphy of sediments under the Ashumet Valley Plume. The top 90 to 140 feet of the aquifer is made up of coarse sediments with the sediments becoming finer as depth increases. Also, the level to bedrock was found under this plume and was assumed to be the bottom of the aquifer. The locations of these boreholes and further analysis was completed from a contour map that had already been developed for the area showing the direction of

[56] Ibid.

groundwater flow and the level to the water table. Thus, from these initial geologic characteristics including the numerical parameters such as hydraulic conductivity for the soils, the plume extent maybe estimated before an extensive monitoring system is installed. This allowed the investigators at the site to focus their site investigation efforts. From the understanding of the groundwater flow mechanisms, it was apparent beforehand where the plume would be migrating. These types of studies greatly improve the effectiveness of sampling and analysis. The next step is to discuss the use of computer modeling which will aid in defining plume movement before investing resources in thorough investigations.

5.2.4. Conceptualization with Computer Modeling

The use of groundwater models has been growing rapidly due to the versatility of computer tools that have become available. These tools range from three-dimensional visualization tools to finite-element codes that model flow through differing media. These computer technologies have been used extensively in the design phase of remediation projects; however, their effectiveness is also useful during the conceptualization phase as well as through the investigation phase. These models are also extremely valuable since they can be updated throughout the process producing an efficient design tool.

Groundwater models are idealizations of the actual groundwater flow in the area with the conceptual knowledge of the site incorporated to construct the model and provide valuable parameters. Unfortunately, these models are still idealizations since no model has the capability to model all of the complicated factors that contribute to groundwater movement. However, these models are still extremely useful throughout the entire process[57]. Data that is collected from future field sampling will provide indications as to the model's effectiveness. Groundwater numerical modeling falls into two different types of methods, finite difference methods and finite-element methods. Finite-element

[57] Vivoni, Enrique R. "The Use of Groundwater Modeling for the Remediation of Contaminated Aquifers". Massachusetts Institute of Technology. 1.781 - Environmental Restoration Engineering.

models are particularly useful since the space that is modeled may be divided into elements that are of differing spatial magnitudes. Finite difference methods do not have this capability. With the finite-element method, small elements may be used in the areas of concern providing the most accurate results. Theoretically, as the elements become smaller and smaller, the model will accurately predict the flow conditions from the assumptions. Unfortunately, these models are limited due to computing speed and numerical error with intensive calculations. However, these results, although not perfect, provide a useful indication of plume movement and the prediction of future conditions.

The groundwater models that are being used in remediation today are extremely versatile. Groundwater flow models are included in packages along with models for vapor transport and non-aqueous phase liquids (NAPLs). The groundwater flow models use the hydrogeologic data that is obtained from the conceptualization to determine the direction and flow rate of the groundwater at a site. Flow models are typically two-dimensional considering flow in the horizontal direction in aquifers. These idealizations are made for model simplicity. Once this hydrogeologic data is inputted along with site characteristics, the model may be used to predict the contaminant flow through the groundwater.

These models may be used in the conceptualization phase to better understand the flow of contaminants and to locate areas for effective sampling. The following discussion outlines an example illustrating the use of groundwater models in the process and what data is needed for model construction[58]. At a site with a potential spill, the remediation managers will collect hydrogeologic information that is needed to characterize the site. Several different methods may be used to determine hydraulic conductivity, soil porosity and water table depths throughout the area of potential contamination. Also, geologists in conjunction with the hydrogeologists determine the types of soils that are present and describe the soils properties quantitatively. The next step involves producing profiles of

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[58] Ibid.

the soil stratigraphy at the site as shown with the Ashumet Valley plume. Finally, the sources and discharges of the aquifer in question must be understood. Also, the affect of wells that are already present in the vicinity of the site must be determined. These wells may be used for preliminary sampling if preliminary quantification of contaminants is needed. Thus, in this case many of the site characteristics are already understood without installing expensive monitoring wells. The next step is to use the computer model with the necessary parameters and inputs required to predict the rate and extent of the plume.

To fully characterize this spill the contaminants must be identified and the rate and extent of the groundwater plume must be determined. This must be completed by installing monitoring wells and extracting samples at different depths. A computer flow model serves as an effective means for determining the placement of these monitoring wells. This becomes an iterative process. The computer model is used to predict the placement of initial sampling wells. These wells should successfully indicate contamination since the model indicates likely plume location. This data may then be integrated into the model and further sampling may be completed if necessary. Through this process the chance for no-detects of groundwater contamination is lessened and fewer monitoring wells are installed. Thus, computer flow modeling will decrease the expense of installing too many monitoring wells with a relatively small investment in the appropriate software from the outset. These types of methods are used frequently in remediation projects today and need to be effectively implemented from the front end of the process in the conceptualization and investigation phase.

5.2.5. Computer Modeling of Chemical Spill 4 (CS-4) at the MMR[59]

Unfortunately, many of the plumes at the MMR were delineated with many sampling events using the "poke and hope" method. Computer modeling has been used after some sampling to better understand the characteristics of plume migration. CS-4

[59] Hutchings, Theresa. "Application of Modeling Techniques to Test Hypotheses Concerning the Migration of Aviation Gasoline from a Surface Spill". Massachusetts Institute of Technology. February 1995.

was created from many years of improper disposal of waste by the Defense Property Disposal Office (DPDO). Wastes were transported from around the base and disposed of in the area of CS-4. Potential wastes stored or buried around the site include transformers, electrical equipment, waste oils, solvents and waste fuels. Also, liquid wastes were buried in barrels or in several underground storage tanks. The soils that contained these tanks and barrels have been removed along with the tanks; however, extensive groundwater contamination still exists from the wastes entering the soils in contact with the groundwater. This site is currently paved on the surface and the sediments below the site consist of primarily poorly graded sands with some silt and gravel. This site is underlain by the Cape Cod Aquifer approximately 67 feet below the ground surface. The groundwater at the site has been determined to flow in the south south westerly direction.

The main contaminants from this plume are chlorinated volatile organic compounds that are potential carcinogens in the concentrations found in the groundwater. This plume has currently migrated off base and threatens several wildlife protection areas in the kettle ponds in the area. The plume is currently well below the ground surface; however, kettle ponds pull the groundwater towards them increasing the likelihood that these contaminants will enter the ponds and threaten wildlife.

This plume has very peculiar characteristics from the initial sampling that was completed. The plume has a distinct "cigar shape". It is extremely long and narrow, an unexpected condition with a plume in these types of soils. Typically, the plume would have spread more in the lateral direction. There were two possible considerations to determine why the plume was confined to this shape. First, since the initial sampling events were so preliminary, it was thought that the plume may have spread laterally in small extensions that may have been missed with the initial installation of monitoring wells. The second hypothesis was that a geologic formation in the form of an ancient stream bed may be confining the plume. A computer model was used to evaluate the possibility of these two alternatives. It was difficult to conclude from this computer model why the plume would migrate in this confined manner. However, the computer model gave a definitive idea of what the plume would do in the typical subsurface environment at the site. A three-dimensional flow modeling tool was used to model the flow at the site with the parameters determined from previous investigations.

The results obtained from the computer model show that it is likely that an ancient stream bed made up of clay is confining the flow in the aquifer. By considering the characteristics of the soils, the computer model predicted that the plume should be twice as large laterally as it actually is. Also, the computer model showed that small lateral extensions of contamination were unlikely given the flow conditions at the site. Thus, the limited sampling with wells probably did not miss any abnormal lateral plume movement. The likelihood of the existence of a clay stream bed in the subsurface is suspected. This theory will require further geologic investigation and understanding. If this geologic unit does exist it is crucial to understand its influence for the effective design of a groundwater remediation strategy. If this unusual flow mechanism is not understood an ineffective pump and treat system may be designed proving very costly. Therefore, this example shows the effectiveness of computer modeling and the added understanding that it may provide. If these tools are used properly, they will prove valuable in helping to understand groundwater contaminant movement.

5.3.Conclusions

It is important for managers of remediation projects to understand the process behind developing a conceptual model of subsurface behavior. For groundwater contaminated sites, developing a complete subsurface model is crucial. This will save resources that need to be committed further in the remediation process. For instance, developing a conceptual model early in the remedial process will aid both site investigations and remedial design. The drilling of monitoring wells for the assessment of groundwater contamination will be optimized. Since wells are expensive to install, they will be placed optimally if the likely area of groundwater contamination is determined beforehand. Thus, "smart sampling" may be practiced instead of relying on the "poke and hope" method of well installation. Also, the use of computer modeling was demonstrated showing how these models may be used to more effectively understand groundwater contaminant transport. These models, when used properly, will benefit both the site investigation phase and the design phase. Also, the consistent building of the model with further analysis is important. Typically these models have been developed primarily in the design phase. With an effort to integrate this towards the front end of the process before the site investigation is completed, more benefits will be noticed. After all, it is unreasonable to expect successful investigations and remediations when the flow processes and underground behavior are not understood. By investing more in this effort directly after site identification, savings will be incurred through downstream activities.

6. SUPERFUND MANAGEMENT CHANGES

6.1. Introduction

The EPA has issued guidelines for a continuing initiative called the Superfund Accelerated Cleanup Model (SACM) which outlines the procedures for the more efficient cleanup of Superfund sites. Basically, SACM involves the more efficient integration of all Superfund activities towards the front end of the process. For instance, efforts are made to coordinate between the removal and remedial authorities so repeat work and unnecessary effort is avoided. SACM was instituted in 1992 as an ideal model which was implemented on a pilot project basis in several regions of the country. The concepts and efforts behind SACM have been instituted due to the extreme cost and time requirements of remediation projects in the past. This effort will influence all phases of the Superfund process considering the needs of all phases of the cleanup from the beginning and making prudent decisions based on future implications. It is hoped that this model for site remediation can be standardized and used on a wide basis throughout the country in the near future.

SACM is a continuing effort on part of the EPA to enhance the risk reduction at Superfund sites. After all, the reduction of risk is the ultimate goal of any remediation project. Unfortunately, in the past, large sums of money have been expended to reduce the risks at Superfund sites to extremely low and unreasonable levels. This new EPA effort attempts to reduce these extreme cleanup standards by considering only the realistic risks for each specific site. SACM also addresses the many administrative inefficiencies that have existed in the hazardous waste process throughout the 1980s. An effort has been made to enhance the decision making process for each site by using Regional Decision Teams (RDTs). Also, presumptive remedies are being used to avoid the needless evaluation of unlikely alternatives that is typical of feasibility studies. SACM consists of the following efforts[60].

1. A continuous and combined process for assessing site conditions and the need for action.
2. Cross program planning between removal and remedial authorities.
3. Prompt risk reduction with an effort towards more realistic risk reduction.
4. Appropriate cleanup of long-term environmental problems.
5. Early public notification along with enforcement activities.

Each of these efforts impacts the site investigation phase of a remediation project directly or indirectly. Although some of these efforts may seem unrelated to the site investigation phase of a project, all of them have implications for the time and money spent on an investigation. One example of this is the use of presumptive remedies. Although this effort mainly streamlines the feasibility study, it also enhances the RI since data collection is focused when the remediation technology has been chosen beforehand. Another example is illustrated in the SACM case study with the Times Beach farm site. By considering the "real risks" posed at the site in conjunction with future use, the site investigation phase is changed dramatically.

6.1.1. Assessing Sites Under SACM

The assessment process in the past has been separated due to the different functions of the removal authorities and remedial authorities. Much of the effort with

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[60] United States Environmental Protection Agency. Early Action and Long-Term Action Under SACM -

SACM has focused around the site assessment process and methods to speed the site through treatment since the greatest impact on project cost and schedule can be made in the early stages of the process. Assessing sites under SACM has several important initiatives. First, the process integrates traditional site assessment activities. Also, high priority sites will be assessed continuously to screen the sites or to support any needed response actions. The assessments are integrated to support both removal and remedial assessments and the activities will support removal actions, listing on the NPL, and long-term treatments. Second, SACM encourages response actions to reduce immediate risk. The assessment for long-term treatment should continue concurrently with any emergency response action. Third, assessments will be conducted so that data collected in one phase of assessment supports other activities including the RI/FS, enforcement and response activities. Finally, SACM reinforces the effort to assess the worst sites first, again to reduce the most immediate risks as expeditiously as possible[61].

The Regional Decision Team (RDT) is an integral part of the SACM process as more decision making authority is given to the parties most closely associated with the site. The role of the RDT is to foster coordination between the removal, remedial and state personnel. In general, the RDT has the responsibility to integrate Superfund activities. The RDT makes the decision for future site treatment after enough data is gathered in the initial assessment. They will convene to consider options which include: directing a response action, deciding to collect additional data, developing an enforcement strategy and considering placement on the NPL. Thus, decisions for each site will be made as soon as possible, expediting the entire process. As stated previously, considering all major Superfund activities at the front of the process is the main goal of SACM. For instance, two activities are considered early in the process; identifying PRPs and involving the community. Identifying PRPs as early as possible will speed the

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Interim Guidance. Office of Solid Waste and Emergency Response. Publication 9203.1-051. Dec. 1992.

[61] United States Environmental Protection Agency. Assessing Sites Under SACM - Interim Guidance. Office of Solid Waste and Emergency Response. Publication 9203.1-051. Dec. 1992.

recovery of funds and allow for more effective cleanup. Also, evidence has shown that bringing the public into the process as early as possible will improve relations and avoid hostility toward activities at the site and the EPA.

6.1.2. Expediting Cleanup with SACM

For sites that require long-term action, the RI and risk assessment will be conducted earlier in the assessment process than in the past. With SACM, the RI may begin before the site is scored on the HRS or placed on the NPL. Thus, during the RI, data may be collected to support the scoring on the HRS. Also, data will be collected for the normal purposes of characterizing the site sources, the extent of contamination, and the risks associated with the site to determine cleanup methods. This streamlined cleanup process is possible with the use of RDTs. Substantial expertise and increased decision making authority is given to these teams enhancing the Superfund process by overlapping activities. However, the success of this effort relies on the ability of the RDTs to determine the likelihood of future treatment at the site. The commitment of extensive resources to a site that will not will not be listed on the NPL will be anti-productive. However, the EPA is willing to take the risk of initiating some RIs before NPL listing to save time and money.

6.1.3. Integrating Removal and Remedial Assessments

This is the most comprehensive effort of SACM which will affect the site investigation activities on a remediation project. This effort began by identifying the redundant work of the removal and remedial assessment authorities. Approaches have been developed to integrate these two activities. The typical site assessment process begins when the state or federal environmental authorities are notified of a potential release of contamination. An on-scene coordinator (OSC) is then dispatched to assess the condition of the site. If the situation poses an immediate threat, there may be an instant action proposed by the OSC. However, the EPA typically prefers to conduct a removal assessment prior to any removal action. The OSC completes a file investigation for the site and conducts an investigation of the site by telephone. The OSC may ultimately take a few samples to determine the status of the contamination. In some cases, the site will not require a removal action. The site may then be referred to remedial authorities or handed over to the state level for cleanup[62].

The remedial site assessment process is very similar to the removal process; however, these activities have been separated since the advent of Superfund. The remedial assessment process is governed by the Site Assessment Manager (SAM) who is responsible for conducting the Preliminary Assessment (PA) after the site is added to the national database, CERCLIS. The focus of the PA is to obtain an initial idea of site contamination and to determine if the site should be scored on the HRS. This site description may usually be obtained without sampling at the site. The PA usually includes a file search of site materials, a telephone investigation and a site reconnaissance. After this preliminary stage, the SAM will then determine if a Site Inspection (SI) is needed. This is necessary if the SAM determines that the site should be scored on the HRS for possible placement on the NPL. The SI usually consists of just enough site sampling to score the site on the HRS. It is stressed that this sampling event is very preliminary and does not in any way substitute for the RI. In some cases, after the SI, there is still insufficient data for HRS scoring. In this case an Expanded Site Inspection is needed. As can be seen, this process is very long and inefficient. It is important to keep in mind that this assessment stage is used only to determine if the site belongs on the NPL. The Superfund remedial process including the RI/FS, remedial design, and remedial action still have to be completed before the site is deemed clean.

There are many similarities between the removal and remedial assessments; however, they have been separate for several reasons. First, the two assessments do have different purposes and agendas. It is a management challenge to coordinate these two

[62] United States Environmental Protection Agency. Integrating Removal and Remedial Site Assessment Investigations. Office of Solid Waste and Emergency Response. Publication 9345.1-16FS. Sept. 1993.

activities to ensure that both parties have fulfilled their regulatory requirements. An attempt to discuss this integration and management challenge is being tested at certain pilot sites around the country. Some regions have effectively implemented these ideas drastically reducing the assessment period which may have encompassed a 3 year period in the past on some projects[63].

It has taken a change of culture for these two assessment events to be integrated into one efficient process. The removal site assessment lacks structure since they are time pressed to determine potential action especially in emergency situations. The remedial site assessment, on the other hand, is more structured and takes place in a non-time critical environment. In short, the remedial authorities are interested in gathering data for evaluating the site for the HRS. The removal authorities are interested in determining whether the site meets the criteria in the National Contingency Plan (NCP) for a removal action. The integration effort combines these two goals to satisfy both parties and streamline the process.

While there are major obstacles to assessment integration, there are also many common factors that make it feasible. For instance, both authorities will investigate for human exposure through drinking water, soils and air pollution. Also, telephone and file investigations are similar for the two activities. The goals of integrating these assessments are to:

1. Eliminate duplication of effort.
2. Expedite the process.
3. Minimize the number of site visits and administrative steps in the process.
4. Collect only the data that is needed to assess the site properly.

Assessment activities in the past have taken place in a very conservative environment. Typically, there has been too much assessment at a site and time and

[63] United States Environmental Protection Agency. SACM Update. Office of Solid Waste and Emergency Response. Publication 9203.1-14FS. March 1994.

money has been wasted. Thus, it is important to know which assessments to carry out. Not all sites require both removal and remedial assessments. Thus, the integrated assessment must be tailored to the particular site. For instance, if the site required solely a removal action, the integrated assessment would be carried out similar to removal assessments in the past. *The integrated assessment must be flexible, adding to its efficiency*[64].

The first step in an integrated assessment is the notification stage where both removal and remedial authorities will determine if the site is an immediate concern. If not, the file search is conducted for both parties considering the requirements of both. The common elements of a file search are: regulatory search, site access and information, site history, substances used at the site, past releases and topographic maps of the site. However, additional data is obtained for removal concerns such as identifying possible PRPs for immediate notification and a preliminary search for removal options if an action is deemed necessary.

The next step for an integrated assessment is the initial field investigation. Only a small increase in effort is needed to combine this activity since they are similar between parties. Some elements that are common to both site visits are identifying sources, human exposure, substances present, evidence of releases, runoff pathways, nearby wetlands and containment evaluations. However, some additional aspects are obtained for removal qualification including fire and explosion threat, urgency of need for response, possible treatment alternatives and some sampling. Unique needs of remedial authorities include needs to: review the perimeter; assess the number of people close to the site; and, review all runoff pathways for proper long-term site assessment. Typically, removal authorities would sample some soils at the site; however, with an integrated assessment the sampling needs of the RI would also be considered. After this initial assessment, the RDT will

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[64] United States Environmental Protection Agency. Integrating Removal and Remedial Site Assessment Investigations. Office of Solid Waste and Emergency Response. Publication 9345.1-16FS. Sept. 1993.

discuss the next steps at the site depending on the risks posed by the contaminants. Three options exist: continuation of the removal assessment; conducting a remedial PA; or doing both concurrently with an integrated team. In all cases, this program should remain flexible addressing the needs of both parties. If sampling events are needed for further removal assessment or the site inspection, all data should be taken with proper quality assurance. These sample results will then be usable in the future for the RI.

This integrated approach to site assessments should save time and money and accomplish the objectives of the effort outlined previously. With proper integration and a flexible approach for assessment, both removal and remedial authorities will obtain the data required for the regulatory environment. The true vision of SACM has been identified as "one program, with all employees working together to accelerate cleanup" [65]. In several regions, this idea has materialized with attempts to implement all facets of SACM. Several regions have made efforts to change the culture of their activities[66]. For instance, Region V has moved their site assessment branch into the removal branch creating cross-coordination between removal and remedial authorities. It has also helped the region institute a "one door" entry for sites with suspected contamination. Region V has also rotated the heads of their removal and remedial branches to enhance each other's understanding of their respective processes. Region V has constructed the Regional Integrated Site Evaluation (RISE) process for proper assessment integration. This process consists of "one-door" entry for sites, and integrated assessments of worst sites first. It also establishes the documentation procedures for this process satisfying regulatory compliance. Thus, the program has ensured a consistent process for integrated site identification, planning, mobilization, sampling and reports. In essence, this effort attempts to overcome the culture created by the regulatory environment in the 1980s.

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[65] United States Environmental Protection Agency. SACM Update. Office of Solid Waste and Emergency Response. Publication 9203.1-14FS. March 1994.

[66] Ibid.

With the EPA becoming more flexible and new attempts at changing operational culture, the Superfund process may become more efficient.

6.1.4. Presumptive Remedies

Many sites have been found to have common characteristics and the EPA is using this approach to provide guidelines and remedies for sites with common contaminants. This use of presumptive remedies also affects the site investigation process. The initiative is expected to help detail and focus data collection efforts for investigations. Initial data collection will focus on determining the site type and whether a presumptive remedy is appropriate. If this remedy is found appropriate, the site specific directive for that remedy is followed. These directives will outline site characterization methods and enhance the investigation process[67]. In short, the use of presumptive remedies has ramifications for the entire remediation process. It is crucial for remediation contractors to be aware of these changing EPA policies and with their corresponding directives.

One of the primary reasons why SACM is so comprehensive is due to EPA's desire to change the entire process based on the experience which was gained in the 1980s. In the 1980s, the removal and remedial programs found that several types of sites have similar characteristics. For instance, sites have similar types of contamination along with similar disposal practices. However, at each of these different sites, the Superfund process was carried out in full even though the typical remediation solution is known well before the feasibility study is finished. Thus, why not assume from the start of a Superfund project that a certain remedy will be used? This will not only expedite the remediation process in general by avoiding unnecessary work, but it will also allow for streamlined investigations. As is evident, the presumptive remedy effort has the

[67] United States Environmental Protection Agency. Presumptive Remedies: Policy and Procedures. Office of Solid Waste and Emergency Response. Publication 9355.0-47FS. Sept. 1993.

potential to substantially change the entire Superfund process. The goals of the presumptive remedy effort are the following[68]:

1. Streamline the site investigation process.
2. Speed the selection of cleanup alternatives.
3. Ensure consistency in remedy selection.
4. Reduce the time and cost required to cleanup sites with similar characteristics.

The EPA will be issuing guidelines for sites that show similar characteristics detailing the process used for investigation and treatment. Hopefully, in the future, these presumptive remedies will be used at all sites with similar characteristics. However, this effort will not be attempted at sites that have unusual types of contamination or special site-specific characteristics. Presumptive remedies should be used because of the up front benefits which may be gained. For instance, limiting the number of technologies considered should focus the data collection effort in both the assessment and RI phases. Additionally, effort may be saved in the remedial design phase since technology specific data may be gathered which will increase the design efficiency.

There are some disadvantages to using presumptive remedies that need to be minimized. Some concerns have arisen due to the conflict of the presumptive remedy effort with the regulatory environment. For example, will presumptive remedies lead to haphazard remedy selection? The EPA is stressing that the presumptive remedy effort allows for the evaluation of alternatives effectively, the process is just being streamlined. The feeling that a treatment for a site is determined totally before site evaluation does not have to hold true. For instance, if a site has similar characteristics with others and qualifies for a presumptive remedy, this does not have to be the choice of remedy. If an EPA region feels that other technologies should be evaluated then the feasibility study should consider more options. After all, even though a site is similar to others, rarely are types of contamination and combinations of contamination exactly the same. Inevitably

[68] Ibid.

there are some characteristics between sites that are different and should be taken into account. There has also been concern about the impact of the presumptive remedy effort on the use of innovative technologies. However, the EPA desires to keep investigating innovative technologies and using them where possible. Unfortunately, however, the use of innovative technologies may be hampered. The risks and money invested in an innovative effort may not be justified compared to treating the site with the "we have used it before and it works" technology. The last potential problem with the presumptive remedy effort is the interaction with the public and PRPs who may desire other cleanup alternatives. The notification to the public that a presumptive remedy will be used should be made as soon as possible. Along with this, the reasons for using the presumptive remedy should be outlined clearly. In most cases, the literature from the EPA will address why alternative technologies are not as effective as the presumptive remedy and the public's concern should be limited. In extreme cases an alternative technology may be added to the feasibility study. Most importantly, the presumptive remedy effort needs to be flexible, allowing for the most efficient path to site treatment.

6.2.Case Study: Times Beach, MO: Risk-Based Decision Making

One of the main problems with the Superfund process is the overinvestment in remediation along with costly litigation. Typically, remedial actions are determined and sufficient data for the reasons for the actual cleanup are not outlined. The PRPs then seek litigation as a method to outline exactly what needs to be cleaned, desiring to pay for as little as possible. One attempt to correct this situation is to use risk-based decision making[69]. This entails reducing the risks at the site to the needed levels as promptly as possible. Regulators are beginning to stress real risk reduction in the practical sense that every citizen will understand. SACM allows this new method of cleanup to be attempted since it allows flexibility in the Superfund process spawning new cleanup management

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[69] Blacker, Stanley and Goodman, Daniel. "An Integrated Approach for Efficient Site Cleanup". Environmental Science and Technology. Vol. 28, No. 11, 1994.

methods. Basically, SACM has given the regulators an avenue to try new, more efficient methods of site cleanup.

6.2.1. Project Background

A small farm near Times Beach, MO is typical of many farms in the Midwest. In this case, surface soil had become contaminated with high levels of dioxin. The dioxin was a result of suppressing dust by coating the soil with waste oil, a common practice in many farming communities in the past. Unfortunately, the elements of wind and precipitation had distributed the dioxin over a wide area increasing the cost of cleanup into the multi-million dollar range. The total costs at the site would consist of the contamination identification costs including sample collection and analysis along with all remediation costs including excavation, removal, storage and treatment costs. The cost of this project was less affected by the choice of cleanup than by the amount of soil excavated. The trend in the past has been to excavate unrealistic amounts of soil at exorbitant costs. This case study covers the risk-based decision making approach that provides a more realistic method for cleanup. In the case of this project, EPA region VII had seen this type of contamination before in many instances and they were knowledgeable of the typical cleanup approach. Thus, it was interesting to evaluate if this new investigation and cleanup method would save time and money.

6.2.2. The "Typical" Treatment of this Site[70]

This site would have been assessed through the typical regulatory process identifying the type of contamination present at the site along with exposure pathway assessment. The site would then be divided into units encompassing 5000 square feet. This delineation of units is the responsibility of the field investigation team. The typical practice is to create units that are long and thin which encompass supposed areas of high contamination called "hot spots". In this case, the dirt roads where the dust suppressant

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[70] Blacker, Stanley and Goodman, Daniel. "Case Study: Application at a Superfund Cleanup". Environmental Science and Technology. Vol. 28, No. 11, 1994.

was used would be targeted as areas of higher contamination. Also, areas of run-off such as gullies would be targeted for supposed high levels of contamination. The investigation then proceeds to determine the levels of contamination within each unit. The units are divided into square grids with 50 points. At each grid point, three samples of soil are collected. One of each of the three samples is composited with the other 49 samples taken. Thus, each unit is represented by three composites, each containing 50 soil samples. In this case, each of the three composite samples is analyzed with a Gas Chromatograph/Mass Spectrometer (GC/MS). Thus, for each unit, three samples are analyzed obtaining three concentration levels for each 5000 square foot unit. To obtain the concentration for the unit, the three concentrations are averaged and a t-test is used to compute the 95% confidence level limits on the average.

The treatment method for the soils is a very simple process. If the upper confidence limit obtained from the concentration is less than 1 ppb, the unit is declared clean and no excavation is needed. If the upper confidence limit is greater then 1 ppb, the unit is contaminated and the soil is excavated to a depth of 4 inches, removed, and backfilled. This method has been accepted in the past as a sufficient method to clean the site. However, due to the inherent uncertainties in this process, some officials thought that there were other ways to clean the site more efficiently using the flexibility allowed with SACM. Some EPA officials were not comfortable with the way units were defined in the process. Basically, it was expert judgment that was used for the layout of the units with no real scientific procedures used. Therefore, the average concentration of the unit was based on a non-scientific judgment call. Using this method, there is an interesting variable that is introduced into the problem. By choosing the units in one configuration, more or less soil may be remediated as opposed to other unit configurations. An illustration of this is shown in Figure 15.

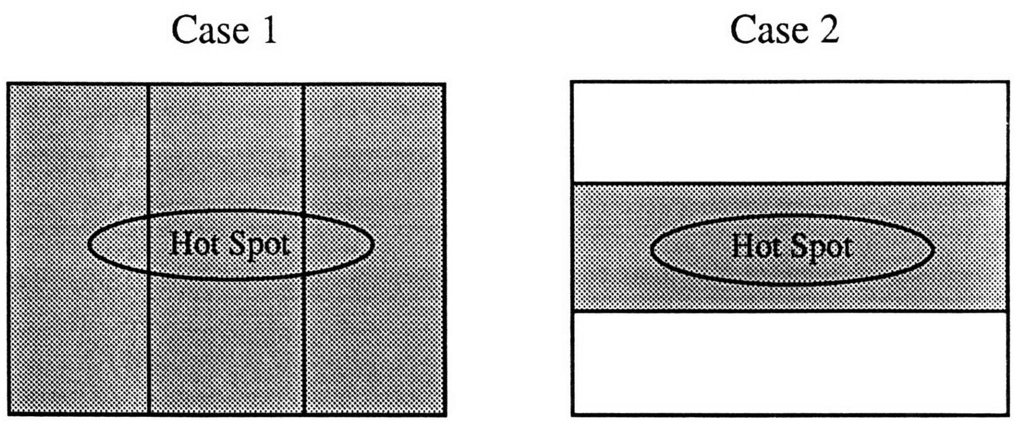

Figure 1: Comparison of Investigation and Remediation Strategies

In case 1, the hot spot crosses the boundaries of the units increasing the likelihood that the entire section will need remediation. This is indicated by the shaded area. However, in Case 2, only one-third of the entire section will need remediation. This is due to the hot spot being contained solely in one unit. The point of this is to show the problem with the old way of remediating a site with this type of contamination. The remediation is effective in that the areas that need remediation will be cleaned; however, it is not the most efficient method. Just due to different investigation strategies with different unit configurations, the soils remediated in Case 1 represent three times the volume excavated in Case 2. A more standardized, consistent method for investigating and treating a site of this nature is outlined further in this case study. The differences in treatment due to unit layouts are avoided and disputes leading to litigation may be avoided. Also, as will be seen, the cost of remediation is decreased with this new approach.

1.1.1. A New, Innovative Treatment Option Under SACM[71]

The first step in the new approach to this soil cleanup project was to address some of the policy issues so agreement between all parties is assured. To satisfy all of the parties, decisions were broken down into policy calls and tactical decisions. In general, the policy calls were non-negotiable during the entire remedial process. An

[71] Ibid.

example of a policy call would be the acceptable level of risk for the site. This factor is set. Tactical decisions focused around issues regarding potential cleanup methods. As long as the policy calls were met, the tactical decisions were negotiated. Essentially, this process boils down to satisfying the regulatory authorities on policy issues as long as they are flexible with other decisions when policy calls are met. This approach improved the atmosphere between stakeholders. It was also viewed as a way to limit litigation allowing the responsible parties to clean the site in a flexible manner as long as policy calls were fulfilled. This new flexibility, allowed under SACM, added many efficiencies to the project.

There were many parts of the cleanup that were already completed at the onset of this new approach. The regulators in the region had a strong working knowledge of dioxin contamination of this nature. Thus, they already were aware of the viable options for cleanup. The presumptive remedy of excavating the soil to a depth of 4 inches and backfilling was chosen. The evaluation of many different treatment alternatives was avoided saving time and money in the RI/FS stage. Also, the known mechanisms of transport and transformation, routes of human exposure, the analytical methods, options for soil treatment and methods of excavation were all well practiced and documented. The future site use for the site was determined to be residential. From this, the parties agreed that the critical methods of exposure were the ingestion of soil and dust. Also, the use of GC/MS was known to work well for dioxin. Unfortunately, for this project, field analytical methods were not used which could have increased savings further.

There were still other decisions to be made regarding where to remediate at the site. This is a critical decision at any Superfund site since the remedial action phase is so expensive. Excavating more soil than is needed adds significantly to the cost. There are also concerns as to when remediation should be stopped. For any project, the strategy is simple. Where the concentration of dioxin is too high, remediate. Where it is below the standard, do not remediate. This is an obvious statement; however, it is not one that is practiced consistently. What was needed for this project was to define the level of contamination that is considered "too high". The standard risk that was used is from reference values that have been used in the past. For carcinogens, the general accepted residual risk is 10^{-4} to 10^{-6} lifetime risk of cancer. This number is defined as plausible assuming worst case exposure scenarios. All of the plausible outcomes are structured considering dioxin as a contaminant, the exposure routes and exposure levels, the transport mechanisms and future site use. The worst case scenario is the most severe 2.5% tail of plausible outcomes. The risk associated with each scenario is calculated from nominal dose-response curves. Although these curves are subject to serious uncertainty with many of the results from laboratory animal tests, these curves must be used since they are the only standard available.

For the dioxin contamination site, ingestion was determined to be the worst case exposure with the future use defined as residential. A dose-response curve was established that satisfied regulators from the Center for Disease Control as well as from the EPA. From this, a concentration of 1 ppb was established as the level which gives a residual risk of 10^{-6} lifetime chance of cancer. The next step was to define the areal extent of reasonable expected exposure. Considering that this was a residential area, the smallest reasonable use area was defined as a residential lot approximately 5000 square feet. Typically, residential lots are shaped rectangularly so an agreed upon grid of units the size of 50 feet wide by 100 feet long was accepted. This was in contrast to the old method of using judgment to determine unit dimensions. With this new innovative approach, the unit sizes were determined based upon actual future usage of the site. This is a more reasonable solution helping to reduce the real risk posed by the site. One other assumption was made with this configuration of units from the flexibility using SACM. It was assumed that only the average concentration in the 5000 square foot unit was critical. If small hot spots existed, the average for the unit may still be below the threshold level of 1 ppb; thus, no remediation would be needed.

Therefore, the new procedure for investigating and remediating this site may be contrasted with the old method. Using the new method, the site is divided into units approximately 50 feet by 100 feet. If the unit has an average concentration above 1 ppb dioxin, then remediate until the average for the unit is below the threshold of 1 ppb. The old method was different in that the remediation approach for each unit was to excavate the entire area or none at all. With the flexibility of SACM, only a portion of the unit could be excavated reducing the average concentration below 1 ppb. Thus, no further remediation is needed since the risk for the unit, defined as the risk for a residential lot, is below acceptable levels. The type of treatment is termed risk based decision making. In the past the risk did not factor directly into the investigation and remediation process.

The next step was to outline the modified investigation technique that would be used with this new flexible model. Unfortunately, this raises many interesting issues since analytical results are only an estimate of the actual concentration of dioxin. This is due to analytical error. Due to the nature of the contamination, it was believed that extreme hot spots were not likely with the dioxin; thus, regulators agreed that it was satisfactory if 5% of the units were left with average concentrations above 1 ppb. This was the error they were willing to allow. The next step was to determine the details of the sampling plan to ensure an error rate of only 5%. This is one of the most challenging stages of this new investigation and remediation approach. The size of the smallest cell within the unit that should be remediated needed to be determined. If the cells were small, the precision of the remediation would increase. This corresponds to remediating only the hot-spots and not remediating any clean dirt. However, to achieve this, the cost of sampling and analysis would increase. Thus, the savings from not remediating clean soils must be balanced with the cost of sampling and analysis. Unfortunately, this kind of cost comparison could not be made with any of the data at the site. A pilot study of one area of the site was conducted since it was deemed worthwhile by the regulators. It was felt that the pilot study would save money in the long run by providing needed data.

Several basic concepts were determined before beginning the pilot study. If the contamination at the site is more "patchy" the cell size would have to be smaller to delineate the average concentration effectively. Unfortunately, from past sampling only composite samples had been taken which did not provide this data. For the pilot study, an area was used which was thought to represent the worst patchiness of contamination. From the samples taken in the pilot area, the optimum cell size and number and pattern of samples per cell was determined using statistical analysis. The optimum was determined by finding which cell size provided the lowest remedial cost. For this case, the optimum cell size was determined to be 14 feet by 14 feet with 9 samples taken uniformly in the cell. The nine samples were mixed to provide one composite sample from each cell. Each composite was analyzed for concentration levels. Thus the new method for site investigation and remediation may be outlined. The steps in the new remediation process are:

1. Divide the site into units that are 50 feet wide by 100 feet long. The dimensions are now slightly less to accommodate the 14 foot by 14 foot cell size.
2. Obtain three composite samples for each unit as in the old method and find the dioxin concentration average. If the average is below 1 ppb, then no further action is taken. If it is above 1 ppb, then the following steps are taken.
3. Subdivide the unit into 14 foot by 14 foot cells and obtain one composite of nine samples from each cell.
4. Find the smallest number of cells that need to be remediated to decrease the concentration below 1 ppb for the upper 95% confidence level of all the cells in the unit.

This procedure is obviously very different from the old way of conducting this remediation. Actually, until step 3 in the above guide, the process is the same as the old method except that standard units of 50x100 feet are used. The new method is advantageous in many ways. First, the highest areas of contamination are excavated thus reducing the overall variability of concentrations. Also, substantial monetary savings were incurred for the project as a whole. In total this new approach saved approximately 50% for a cleanup that ended up costing $10 million. To ensure that the method was working well, a strict regiment of QA/QC was used to sample units after remediation. The success of this new method was confirmed to have reduced the real risk at the site focusing on realistic factors such as equating the risk posed to a field concentration standard.

6.3.Conclusions

From the discussion of SACM, it is evident that there are many areas where the Superfund process may be improved. SACM includes efforts in all phases of the process from initial notification of contamination, through assessment, to remediation with presumptive remedies. Unfortunately, this effort has not been tested thoroughly in many regions of the country so it will be a continuing effort gaining momentum if proven successful. The case study of the Times Beach farm contamination illustrates just one important aspect of the process. The case shows how the "real risk" at a site may be reduced efficiently without considering unrealistic risks. Also, the cleanup criterion was directly related to the risk determined for a residential future use. This cleanup strategy has interesting implications for the site investigation phase of a project. As seen in the case, the site investigation strategy was changed dramatically from the old method. However, to actually reduce the life-cycle cost of the remediation, more samples and analysis were taken with the new method. Thus, the site investigation costs were actually increased while the costs for the remedial action phase were decreased. The total project costs were decreased resulting in a 50% savings. It may have been possible for the use of field screening methods on the project; however, concentration averages were being used to evaluate cleanup decisions so a technology such as immunoassay may not have been useful. Therefore, cost reduction in the site investigation phase is not the only method for remediation improvement. Cost may be saved by increasing investigation expenditures reducing the project life-cycle costs.

7. *Recommendations and Conclusions*

7.1. Overview

In the first part of this overview of site investigations, many of the inefficiencies and problems with typical Superfund site investigations were outlined. The reasons for these problems were many including the regulatory environment and also the desire to obtain payment for the cleanups from PRPs. Also, the remediation industry was young in the 1980s and the inexperience with the entire Superfund process contributed to the excessive costs and time needed for a site to be remediated. As the experience with hazardous waste site investigations has increased, the process has become more and more efficient. Innovative methods for the assessment of hazardous waste are changing the site investigation process. With the cooperation of regulatory authorities, these new methods will have a long-lasting impact on the site investigation phase of a remediation. These methods will also be used outside of the Superfund process as more power is handed to state authorities for cleanup. For instance, dealing with hazardous waste on construction projects will become more prevalent as brownfield development enhances our cities and developed areas.

7.1.1. Field Analytical Methods (FAMs)

The first method discussed for the improvement of site investigations is to consider the use of field analytical methods instead of the traditional laboratory analysis that has been required in the past by regulatory authorities. Unfortunately, the regulatory culture is extremely resistant to change and these tools have not been implemented to their fullest. Remediation managers believe that these methods are effective and cost and time beneficial. However, their efforts to use them have encountered barriers. The federal and state authorities have allowed for their use only in pilot programs. For instance, the Norwood Case Study illustrated the EPA's effort for the use of this innovative technology. For this project, immunoassay kits were used for the analysis of PCB concentrations. Along with proper confirmatory samples, the accuracy of the immunoassay was assured while at the same time providing both cost and time benefits. The detailed Sampling and Analysis Plan (SAP) that was outlined was the key to the success of the project. The quality of the investigation was assured with the sampling process laid out entirely beforehand considering the inaccuracies of the immunoassay and methods to reduce the error. The Central Artery/Tunnel project illustrated the issues that need to be addressed when hazardous waste is suspected on a construction project. The site investigation process was discussed thoroughly which is almost synonymous with the Superfund site investigation process. The use of FAMs was investigated; however, their use on the project was extremely limited. Unfortunately, this project was governed by the Massachusetts DEP which has been conservative with the use of FAMs. Although both the use of immunoassay and field XRF spectroscopy were approved by Camp Dresser & McKee, these methods have been used rarely. Many parties have presented options for the use of these technologies to the CA/T management; however, the resistance has been strong. This is unfortunate because a substantial amount of time and money could be saved with their use.

7.1.2. Developing a Conceptual Hydrogeologic Model

The second innovative method discussed was focusing effort on the understanding of the subsurface behavior at a groundwater contaminated site before the drilling of expensive monitoring wells. This thought process is obvious; however, it is not practiced effectively at most contaminated sites. With a qualified hydrogeologist, analyzing the available information at a site may be completed without expending substantial resources. Data from the site is then incorporated into the conceptual model of the contaminant flow in the groundwater. Thus, the direction and extent of the plume may be estimated allowing for "smart sampling" instead of the traditional "poke and hope" method. As was seen with the MMR case study, geologists and hydrogeologists have tried to understand the subsurface at the site completely before the investigation process was initiated. This involved studying the regional geology and focusing on the geology and hydrogeology in the plume area. Also, the use of computer modeling was discussed with its potential to aid in the understanding of groundwater contaminant migration. Using computer modeling while building the conceptual model will enhance site investigations. Also, advantages are witnessed downstream with this model's use in the design and remedial action phases.

7.1.3. The Superfund Accelerated Cleanup Model (SACM)

This initiative consists of many different efforts to speed the cleanup process that are being tried in each of the Superfund phases. For instance, the typically separate removal and remedial assessments are being combined into one activity. Also, an effort is being made to focus on realistic risk reduction at hazardous waste sites. This has impacted the site investigation phase of a remediation project. The farm site case study in Missouri illustrates both the typical site investigation process and the new process considering real risk reduction taking into account end-use and equating risks to concentrations of dioxin at the site. In the end, more resources were spent in the investigation phase; however, the total remediation cost was reduced by half. The EPA is trying to implement SACM at several sites throughout the country on a pilot project basis. Finally, an effort is being made to address the problems with the Superfund process from the experience that has been gained in the 1980s. This model is sure to change and evolve as new approaches are tried; however, the focus on realistic risk reduction considering end-use will be a primary focus. After all, the purpose of every remediation project is to reduce the risks posed by hazardous contaminants.

7.2. The "Ideal" Model

Although it is difficult to develop an all inclusive model for investigating hazardous waste sites, the thought process must be outlined. On remediation projects, the development of the Sampling and Analysis Plan (SAP) is the step where the site investigation is delineated. All decisions regarding technology use and quality assurance must be made when this plan is developed. The SAP outlines the sampling objectives, strategies and appropriate QA procedures necessary to meet project objectives. The SAP is a site specific document that outlines all site investigation strategies for use throughout the entire process[72].

The first step in developing a SAP is to determine the objectives of the project and to determine the levels of quality that the data must meet, called Data Quality Objectives (DQOs). The objectives outline the extent of investigations required for the site while the DQOs outline the acceptable level of uncertainty that a site manager will accept. The second step is to outline the sampling design for the project. This step builds on the first since the data collection should focus on the objectives and proceed no further. The design identifies the number, type and location of samples that are needed to achieve the project objectives and provide data of the necessary quality. Typically, these schemes are derived from statistical means as outlined in the case studies. Also, this phase should incorporate the new innovative methods for site investigations. All three methods should be considered and used when appropriate. For instance, the use of

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[72] United States Environmental Protection Agency. Quality Assurance for Superfund Environmental Data Collection Activities. Office of Solid Waste and Emergency Response. Publication 9200.2-16FS. February 1993.

FAMs should be considered if the DQOs can still be met. For the sampling design to be most efficient the trade-offs between response time, analytical costs, number of samples, sampling costs and level of uncertainty must be balanced. The use of available resources should be optimized.

The third step in developing a SAP is to specify the methods for sampling execution. This phase involves the establishment of the standard practices that will be used for the collection and documentation of samples. These sample execution procedures are outlined in standard procedures defined by the EPA. These procedures include a description of the sampling method, the equipment that is to be used, and containers that should be used for sample collection and storage. In this phase, the quality control procedures are outlined. The number of background samples needed along with duplicates and blanks are determined. The fourth stage of SAP development is to define the strategies for sample analysis. The use of laboratory analysis or non-CLP services needs to be outlined. Also, the field staff needed for analysis is determined if FAMs are being used. The analytical methods must be chosen properly to obtain the exact data that is needed. Finally, the consideration of using an on-site laboratory should be analyzed. The final step in the process is to define procedures for the assessment of data quality[73]. It is essential to determine if the data is meeting the needs of the project. The data must be of the proper quality to support site decisions. Data assessment involves analyzing the QC samples to assess the uncertainty in the samples. Also, an effort should be made to assess the laboratory quality. The total uncertainty of the sample analysis should be determined by assessing the two types of error with environmental sampling; sampling variability and measurement error. This will aid in determining data usability. The development of the SAP considering the innovative methods outlined in this thesis is shown in Figure 16.

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[73] Ibid.

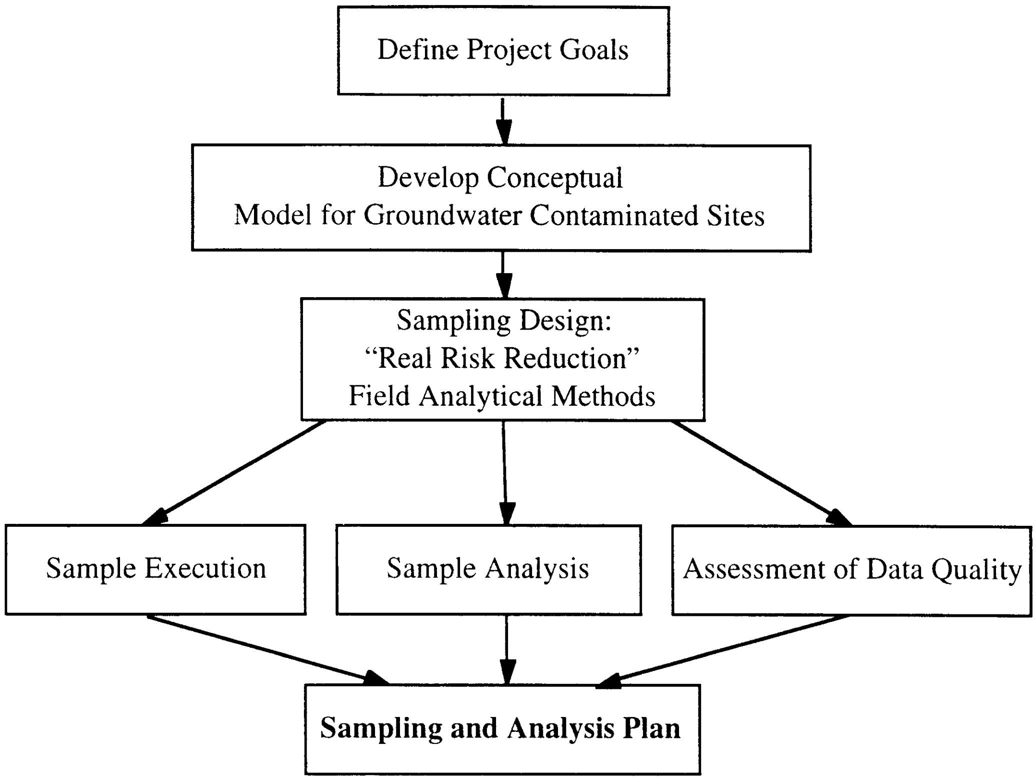

Figure 16: Development of a Sampling and Analysis Plan

7.3. Final Recommendations and Future Research

The key to successfully completing a site investigation stems from the successful development of an SAP with the proper incorporation of the innovative methods discussed in this thesis. However, this plan must also be flexible in nature, changing as the site investigation proceeds. Also, substantial effort must be placed into customizing a plan for each site. For instance, FAMs need to be researched thoroughly before their use to understand the effectiveness and the relative accuracy of the methods. In some cases, combinations of contaminants can interfere with field analysis making it vital that these problems are understood. Thus, the SAP provides the guide to a successful site investigation, one that avoids the inefficiencies found in the 1980s. These plans need to be developed whenever hazardous waste is encountered for potential Superfund sites or for construction projects where waste is suspected or encountered during excavation. Incorporating a conceptual model, field analytical methods and focusing on real risk reduction in the SAP will streamline the site investigation process. These methods will help to save both time and money during the site investigation phase and will also aid the remedial design, the remedial action, and through to the operations, maintenance and long-term monitoring phase. Streamlining all phases of the process will hopefully help the stagnant performance of Superfund.

There are several areas of follow up research that may aid the streamlining of the site investigation process outlined below:

1. Review of new technologies as they enter the marketplace. Also, review which technologies are being approved by the EPA. Since there are thousands of new innovative assessment technologies, an effort should be made to understand which are the most beneficial. For instance, immunoassay technology is currently the most promising method. What other methods will have the same impact in the future?
2. Since regulatory authorities have been a huge barrier to the use of field analytical methods, an investigation of ways to alter this bias should be completed. Also, methods to outline the reliability of these field methods should be discussed which would positively influence regulator biases.
3. Further research into the use of computer modeling from the outset of the remediation process. Computer models have the potential to drastically enhance site investigations. New developments in this field should be studied.
4. The progress of the Superfund Accelerated Cleanup Model should be monitored. Will this effort prove effective and catch on beyond pilot project testing? How does it affect all phases of the remediation process? Is this the answer to Superfund's slow progress?

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